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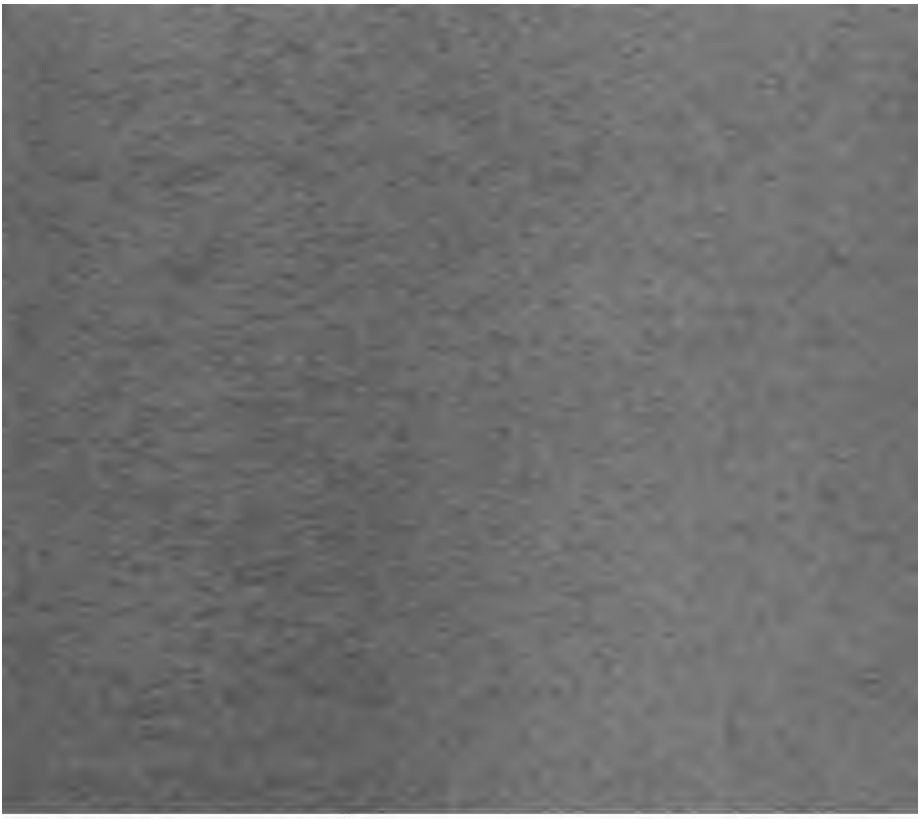

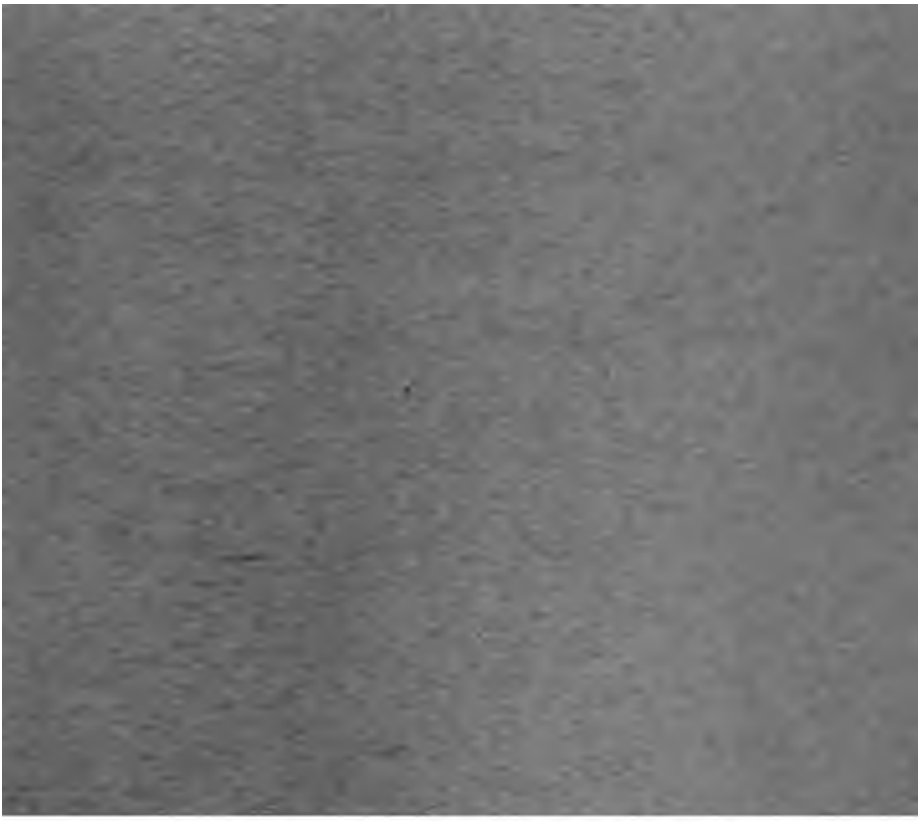

TRANSACTIONS

OF THE

Royal Geological Society

OF

CORNWALL.

INSTITUTED FEBRUARY 11th, 1814.

VOLUME THE TWELFTH.

"Geology in the magnitude and sublimity of the objects of which it reats, undoubtedly ranks, in the scale of the sciences, next astronomy: ike astronomy, too, its progress depends on the continual accumulation of bservations carried on for ages."—SIR JOHN HERSCHEL, Bart.

PENZANCE:
SOLD AT THE MUSEUM OF THE SOCIETY.
1905.

Royal Geol. Society
24.
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Royal Geological Society of Cornwall.

THE EIGHTY-SECOND

ANNUAL REPORT

ETC. ETC.

PENZANCE
1896.

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THE

ANNIVERSARY ADDRESS OF THE PRESIDENT,

T. ROXBURGH POLWHELE, ESQ., M.A., F.G.S.

To the General Meeting, 8th November, 1895.

LADIES AND GENTLEMEN,—My first duty this afternoon is to thank you all for having elected me as your President for this year. It is a proud position for any Cornishman to occupy, this Chair, which has already been filled by so many of our distinguished countymen, as well as other eminent Geologists. The progress of Geology in this county having been so recently ably summarised by your late President, Mr. Howard Fox, leaves nothing for me to mention on that point, and it will be needless for me to take up your time with that subject. Especially as, the Geological Survey having now entered the county, we may expect soon to hear of some interesting subjects for discussion from Mr. Ussher, the Geological Surveyor.

Our thanks are due to those gentlemen who have sent us papers on the geology of the county, especially to Mr. J. H. Collins for his most interesting series of notes on the Cornish fossils, which, I trust, will some day be published in a separate form for easy reference.

I have also to call your attention to those of our members lost to us during the past year; but as this will appear in the Council's Report, a repetition by me is needless. There is one name, however, which I cannot refrain from mentioning, viz., that of Mr. William Bolitho, who was your Treasurer for many years, and has perhaps done more for this Society than anyone. He has shown his interest in the Society to the last by leaving a

sum of money for the purpose of giving a gold medal, for such member whose attainments, labour, and discoveries in Geology or Mineralogy shall best deserve recognition.

By a clause in his will, this medal cannot be awarded until the cost of a die has been paid for; but I have the pleasure of being able to announce to you to-day, that his brother has nobly come forward and paid for the cost of the die, so that the medal can now be given as soon as the interest of the bequest is sufficient for the purpose.

Our thanks are due to Mr. R. Bolitho and Mr. Millett, for the trouble they have taken in getting a suitable design for this medal.

I have also received a letter from Mr. Richard Bolitho on this subject, in which he says:

"DEAR MR. PRESIDENT,—Although a matter somewhat, perhaps, of a delicate nature, I feel I must be permitted, notwithstanding, to allude to the bequest to your Society by my deceased brother and your late Treasurer, William Bolitho, of Ponsandane. Of the safety of the investment of the legacy, not a doubt exists in my mind; at the same time, I cannot close my eyes to the very small income derived therefrom, thereby defeating in a great measure the object desired to be attained.

"This has caused me no little anxiety, as I feel, on greater consideration, such a course would have been in direct opposition to the wishes of my late brother. Under such circumstances, I trust I may not be considered officious in requesting to be permitted to supply the missing link at the earliest possible moment. With this object in view, I have caused a die to be prepared, and a medal struck, which I now beg to submit for the approval and acceptance of your Society."

The die, and the first medal cast from it, lie on the table for your inspection and acceptance.

Since the appointment of our own caretaker the Museum has been better kept, and, I am glad to say, is in perfect order; but the interest taken in the Society is far from what it ought to be, as the lack of attendance at the annual meetings, and the reduced number of subscribers clearly show. Popular lectures have been tried, but prove to have been a failure, only eight being present at the last one.

It is time, therefore, that we take this matter into serious consideration, and try to educate the county in some other way, so as to make the Society more useful. Papers on Geology must needs be technical, and therefore appreciated only by those who are advanced Geologists.

But I do not see why the President, who has a free hand, should confine himself to elementary Geology and ignore the principles, which would be more popular with the general public, and so educate them up to a love of the science.

I will therefore, with your permission, confine myself to-day to the principles, taking for my text, "The relation of other sciences to Geology." Almost every science is a handmaid to Geology. Biology, Zoology, and Botany help us to chronicle the age and sequence of the different strata. Mining, Engineering, &c., all help. But Astronomy and Chemistry will be sufficient for our purpose this afternoon. Geology, as you know, means the history of the earth; a Geologist is, therefore, the historian of the earth.

When a historian writes the history of a country or people, he commences from its birth up to his own times, using the best evidence he can procure; after a time further, or better, evidence is brought to light, enabling succeeding authors to correct the former account. Take, for instance, Layard's discoveries at Nineveh, the opening out of Pompeii, the discovery of that most remarkable evidence—"The Rosetta Stone"—now in the British Museum, which gave the key to Hieroglyphic literature (see Miss Edwards's *One Thousand Miles on the Nile.*) The Geologist, therefore, being the historian of the earth, a history of which has already been written, must, likewise, collect further and better evidence for the purpose of compiling a better and truer history, not omitting discoveries made in other sciences.

It was for this purpose the Geological Society, with its numerous branches, was formed. You see, therefore, how necessary it is for local societies to collect facts, not theories—and then try to find evidence to bear out their theory.

To account for several phenomena in the earth's history, such as upheaval of mountain chains, faults and cleavages in the strata, &c.,

changes of climate; to account for the coal-fields now in the Arctic regions, which must have had heat, light, and moisture for their formation—Elie de Beaumont, Sir R. Murchison, and many other geologists were of opinion that the "history of the earth consists of a series of periods of tranquillity, each separated from the former by a sudden and violent convulsion."

About thirty-five years ago it was thought a change in the axis of the earth might be a possible cause for this, but astronomers said there was no evidence of an evagation of the Poles. However, in 1861, the Astronomer Royal, having found some discrepancies in astronomical observations, was led to the conclusion that there must be an evagation of the Poles. Upon this Sir Henry James suggested a probable cause for this, the substance of which was as follows:

Take any point, such as Disco Island, in lat. 70, and draw a circle passing through it and the North Pole of the earth—this is the circle of evagation. Then, if a sufficiently heavy mass should be raised in the position of the desert of Gobi—the "grand plateau central" of Asia of Humboldt, in lat. 45, the effect would be to cause the pole of the earth to traverse the circle of evagation, but without producing a change in the direction of the axis of the earth in space; but simply a continued change in the geographical position of the pole along the circle. The diameter of the circle would be in proportion to the mass which disturbs the equilibrium. The period of traversing the circle of evagation would, if the earth were of uniform density, be 300 days; and if the density regularly increased from the surface toward the centre, would be 320 days. If, therefore, the discrepancies in the astronomical observations which have been noted by the Astronomer Royal in his report to the Board of Visitors, in 1861, are really due to what he has thrown out as a possible cause for them, viz. "that the axis of rotation changes its position"; these apparent discrepancies should, in reality, follow a definite law, and have a periodicity of about 320 days.

The earth is a spheroid of revolution, and its form is derived from its revolution on its axis; and everything points to the conclusion that it is still a fluid mass within, and all but perfectly free

to assume the new form which its revolution on another axis would produce.

Under the supposition, then, that a disturbance in the equilibrium of the earth has been produced, and that the pole commences to wander along the circle of evagation, it might proceed a certain distance without breaking up the hardened crust; but after a while the crust of the earth would be suddenly broken up, the equilibrium again restored, and the earth would continue, for another vast period to revolve on the new axis, but with a change in the geographical position of the poles, and of the equator. If we seek for a probable cause of such a disturbance in the equilibrium of the earth, we shall probably find it by an attentive consideration of what must take place from the constant removal of the matter from the continent and its deposition in the sea. Take, for example, the Carboniferous strata of North America, which have an unbroken area of 1,800,000 square miles, but which, before denudation separated the coal-fields in the British possessions, must have had an area of not less than 2,300,000 square miles, with an original average thickness of not less than 20,000 feet. Now from the manner in which the land and marine fossils are intermixed throughout the greater part of this formation, it is obvious that the depression of this vast area must have occupied an inconceivably long period, and that it must have been a period of tranquillity, during which not only the Carboniferous series of strata, but all those under them, probably upwards of 100,000 feet thick, were pressed down into a great curve.

Professor H. D. Rogers has conclusively shown that all this material must have been derived from a continent which formerly occupied a large space in the Atlantic Ocean; and as material would be carried away at the same time from all sides of the continent—north, east, south, and west—we can see that whilst the strata were accumulating all round it, the continent itself must have been gradually degraded, and the crust of the earth become there weaker and weaker.

Then take into consideration the enormous tension which the depression of the strata all round it would produce; a time must

arrive when the lower strata of the crust would give way, and there would probably be an outburst of a vast mass of igneous rock, so vast as to produce an evagation of the poles.

As Astronomers now allow that there has been an evagation of the poles, whatever the true cause may have been, let us consider what the immediate results of such a change would be.

First. We should have a sudden change of climate in all parts of the world, except in those parts where the new parallels of latitude intersected the old ones.

Thus, for example, if we assume Disco Island to have been a previous, but recent, position for the pole, the then Arctic circle would intersect the present on the coast of Sweden, and there might be little change in the fauna there; it would pass along the St. Lawrence and the north of Scotland, and we should find that the fossil fauna at those places corresponds with the fossil and living fauna on the coast of Sweden.

Then, if we look at the opposite side of the Arctic Sea, which must then have been 20° lower in latitude, we find the remains of elephants, rhinoceri, and other animals, large and small, which could not possibly have inhabited that country with its present climate. The evidence is equally conclusive that in all parts of the world, but more especially in the Arctic and Temperate regions, that greater or less sudden changes of climate have taken place at every great geological epoch, and without any definite order of sequence in the changes.

Second. We should have evidences of great debacles sweeping over the face of the earth, and destroying the greater part of all the existing fauna and flora, as well vegetable as animal. And referring again to those vast deposits of the remains of elephants, &c., scattered over Siberia, and piled together in New Siberia, to such an extent that the bones form the greater portion of the mass, and from which fossil ivory has been extracted for centuries in large quantities without making any sensible impression upon the vast store, this accumulation would seem, as Pallas says, to have been swept along by agitated waters, buried in mud and gravel. Even an elephant, with its flesh perfectly preserved, was found in the frozen mud of the northern regions;

and, as Cuvier says, it must instantly, and before decay commenced, have been frozen up by instantaneous change of climate.

Then, again, if we turn to the great denudations of the strata which had taken place, such as that which has swept away the Tertiary and Cretaceous strata between the chalk at Reigate and that of Brighton, without leaving a fragment of the previous existing rocks, we must see, as Sir R. Murchison has contended, that nothing but a great debacle could possibly have so swept clean the great valley of the Weald. The same great debacle would sweep away the mass which produced the evagation of the poles, and so restore the equilibrium of the earth.

Third. But if there has been a change in the position of the protuberance of the equator, it must follow that in certain parts of the earth the crust must conform itself to a less space than it formerly occupied, and be thrown into great folds or undulations, having a definite direction with regard to the new position of the poles; and it has been shown by Elie de Beaumont that mountain-ranges are formed at each great geological epoch, and that they have definite directions. But these folds are modified by the previously existing folds of the strata, as waves are when they cross each other obliquely, the point of meeting or crossing always forming the culminating point of the ridge.

The gold-bearing regions, supposed to have been amongst the most recently-elevated folds of the strata, have, as Sir R. Murchison states, a nearly northern and southern direction, like the Ural mountains. It follows, from this view of the subject, that mountain ranges may or may not have a central mass of igneous rock, such as granite. No such central mass, for example, has been observed in the Apalachian chain; and when it is observed, it should rather be considered as a mass taken up in the folds of the strata, and squeezed through them either in rents or between the strata, and not that the mass of soft plastic matter was forced up by some unknown power and forced through hard rocks.

Fourthly. Whilst systems of mountain ranges are thrown up at each geological epoch and a corrugation of the strata is produced, other strata simply show effect of the tremendous pressure

to which they have been subjected by a slight change in the inclination of the strata.

This produces the cleavage in slates, which give evidence of the pressure to which they have been subjected, by the compression of fossils from a circular to an oval form, and by the splitting of rocks themselves into the finest laminæ, as seen in our roofing slates. The direction of the cleavage is modified by the pressure on the central unyielding mass, like granite, along which the cleavage sweeps, partaking in a slight degree of its contour.

Fifthly. The systems of faults are formed, on the contrary, by the strata falling down in certain parts of the earth, in consequence of the changes in the position of the equatorial protuberance, and they being constrained to occupy a wider space than they originally did. The faulted strata, as Sir Henry De la Beche says, seems as if they had first been raised into an arch and then let to fall down; and this nearly describes what must necessarily follow from the change in the form of the earth consequent upon the evagation of the poles.

It follows, then, that if there is any truth in the theory which Sir H. James advanced, the changes of climate, great debacles by which the surface of the earth is ground down and nearly all the pre-existing animals and vegetables destroyed, the formation of mountain chains, the cleavage, and faults in the strata, are all produced by one and the same cause, viz., the evagation of the poles.

But thanks to the improvement in astronomical instruments, Astronomers can go a step further, and say that not only do the poles evagate, but that they can perçeive a slight movement in the axis of the earth itself. If a slight movement, why not a greater in the 200,000,000 (?) years they calculate it took the crust of the earth to solidify before it was divided into land and water, and the various strata which we have to deal with began to form.

Perhaps, of all the sciences, Astronomy has made the greatest advance in this century; when we consider how short a time it is since Galileo was persecuted, by an infallible Church, for saying the sun did not go round the earth. In consequence of the im-

provements in astronomical instruments, astronomers are now able to study worlds not only completed, but worlds in process of formation and decay. They can also give us a fair idea of how worlds are commenced by the collection of aerolites, by the vapours condensing on them as they revolve in space, &c. Chemists can even tell what they are composed of by aid of the spectrum analysis. But the most important new discovery in Astronomy to a Geologist is the detection by Astro of the movement of the pole, and must be regarded as a noteworthy achievement in Astronomy; nor is the result to which it leads solely of interest in consequence of the lesson it teaches with regard to the circumstance of the earth's rotation—it is of great importance in unravelling the geological history of the earth. It is also interesting to Physicists and Physical Geologists, who have been discussing the question as to whether the internal heat, which the earth certainly possesses, is sufficiently intense to render the deep-seated portion of the globe more or less fluid. On the other hand, the effect of pressure at great depths must go far to consolidate the materials to form what must resemble a rigid body. Is the earth to be regarded, therefore, as a rigid mass, or is it not? The phenomena of the tides has already, to some extent, afforded information on this subject, and now Mr. Chandler's investigation adds much further light, for it is certain, from his results, that the earth cannot be a rigid body. In the interests, therefore, of Geology, Mr. Chandler's investigations must be regarded as most important.

In conclusion, let us consider what we have gained by the recent discoveries in Astronomy and Chemistry. We have now their testimony as to the non-rigidity of the earth, and also to the evagation of the poles, and changes in the axis of the earth—two points which Geologists have been contending for in order to explain various phenomena in the history of the earth. Whether a disturbance in the equilibrium of the earth produced the evagation of the poles, or the evagation produced the disturbance, is not of so much importance.

REPORT OF THE COUNCIL.

In presenting their Eighty-second Annual Report the Council feel that no light task devolves upon them, for during the past twelve months events of more than ordinary importance with regard to the Society have taken place.

It is with profound regret that the Council have to record the fact, that within a month of the last Annual Meeting, the Society was deprived by death of a valued friend and adviser, one who had longest borne office—the Treasurer, Mr. William Bolitho, jun., of Ponsandane. Although in somewhat failing health, he was present at the last Annual Meeting, and so sorrowful an issue as that of the 2nd of December last was altogether unexpected. Mr. Bolitho was elected Treasurer in 1859, and held that office until the day of his death—over five and thirty years—and during the whole of that time he never relaxed his interest in the Society, and was especially instrumental in establishing it in its present abode. The old minute-books, no less than the most recent, bear record to his energy and acumen. On more than one occasion he was offered the Presidentship, but always firmly declined it, on the ground that not being a skilled geologist he could best serve the Society in the office he already held. At the latest meetings he attended, a scheme for securing the services of a resident housekeeper, with consequent expenditure in refitting the rooms in the basement, was under consideration, and was a subject in which he was much interested. Unhappily, he did not live to see its completion. How greatly he had the well-being of the Society at heart may be judged from the following extract from his will as communicated by his executor to the Trustees in March last:

"I give and bequeath to the Trustee or Trustees for the time being of the Royal Geological Society of Cornwall domiciled at Penzance in the said County the sum of five hundred pounds free of legacy duty to be invested by him or them in accordance with the terms of the Trust Investment Act 52 and 53 Victoria Chap. 32 the income arising therefrom to be applied in the following manner that is to say in providing the die of a medal by a first-rate artist and when and so soon as the cost thereof has been defrayed out of the income above referred to and not out of principal then to provide yearly and in each year a gold or richly gilt silver medal to be struck from the die provided for above to be called The William Bolitho Medal to be awarded to such member of the said Royal Geological Society of Cornwall whether Ordinary Honorary or Associate whose attainments labours and discoveries in Geological or Mineralogical science shall in the opinion of the President and Council of the said Society best deserve recognition. This medal shall not be awarded more than once to the same individual."

Your Council having duly and thankfully acknowledged the receipt of this handsome bequest, met and considered how the design of the donor could be most readily carried out. It became evident, however, as implied above, that the preliminary expenses would absorb the income derived from the sum bequeathed during the next six or seven years; and, therefore, for the present they felt that they could only wait until the interest should have accumulated to about the sum of £100 (the cost of the die and first medal) before taking action.

This period of inactivity is, however, happily done away, thanks to the thoughtfulness and kind liberality of Mr. Richard Foster Bolitho, who, anxious to carry out his late brother's wishes, has caused a die to be prepared, and a medal struck. He explains his desire to thus benefit the Society in a letter addressed to the President, which has been read to you. The medal is here. It presents on the obverse a fairly accurate portrait in profile of the donor, together with his name and year of birth and death. The reverse bears the arms of Cornwall surrounded by mining implements, including the Davy safety-lamp; with a crown above, the plume of the Prince of Wales and Duke of Cornwall on either side, and the arms of Penzance below; whilst the name of the Society encircles the whole. It is proposed to award this medal at the next Annual Meeting. In consequence of the present

supplementary donation, the Council will henceforth be able to retain a medal in hand.

We have also to lament the death of Mr. James Piers St. Aubyn, one of the Council, and a very regular attendant at its meetings. He, too, was ever a good friend and adviser. He was much interested in all that pertained to the usefulness of the Society, and his technical ability was always at its service. He superintended the recent structural alterations and additions to the basement, so long as he was able, in the earlier part of this year, and died on the 7th May last, at his residence at Marazion. It is yet necessary with very great regret to note further the death of two members who, though both of late removed far from Penzance, were in former times more intimately connected with the Society—viz. the Rev. Thomas Borlase Coulson, M.A., and Mr. James Dennis.

The desirability of having a housekeeper who should reside within the building had long been entertained, and the demise of the Public Buildings housekeeper, who had acted for the three bodies occupying this block as a whole, afforded the opportunity of acting independently. The subject was brought under your notice, and the scheme approved, at the last Annual Meeting. It became necessary to prepare the rooms in the basement, originally designed for the housekeeper, but never hitherto made habitable, for occupation. The work was satisfactorily carried out, and early this year, as caretakers, Mr. John E. Rogers and his wife were selected. They came into residence on the 10th February last, and it is only due to them to state that the result of the new departure, so far as the time which has since elapsed is concerned, is altogether to the advantage of the Society.

The Eighty-first Annual Report, with papers read at the last Annual Meeting, as well as those read at the joint Meeting of the County Scientific Societies held at Penzance, were issued in February last, bringing to a close the Eleventh Volume of the Society's Transactions.

The Reports of your Librarian and Curator will inform you that a goodly number of books have been added to the shelves, by presentation or purchase, whilst the specimens added to the cabinets are comparatively few.

The Monthly lectures delivered in this Museum during the past winter were of considerable interest, and as lecturers we have to thank Messrs. Howard Fox, J. J. Beringer, John D. Enys, and Capt. William Teague. It is only to be regretted that a larger number of persons do not avail themselves of the opportunities afforded.

The next lecture will be delivered by Mr. J. B. Cornish, on "The Point of the Needle," on Friday, the 29th inst., at 8 o'clock p.m.

The Council, in conclusion, desire to recommend the election of Messrs. Thomas Clark, of Truro, and James Caldwell, of Penzance, as ordinary members of the Society.

GEORGE BOWN MILLETT,
Secretary and Curator.

PENZANCE, *November 8th*, 1895.

LIBRARIAN'S REPORT.

From Nov. 1st, 1894, to Oct. 31st, 1895.

THE following works have been added to the Library during the year:

I. TRANSACTIONS, JOURNALS, AND REPORTS.

Presented by the respective Societies, Editors, and other Donors, or purchased.

Adelaide. South Australian School of Mines and Industries, and Technological Museum. Sixth Annual Report, 1894.
8vo. Adelaide, 1895.

Australasian Association for the Advancement of Science. Report of the Fifth Meeting, held at Adelaide, South Australia, in September, 1893.
8vo. Sydney, N.S.W., 1894.

Boston. American Academy of Arts and Sciences.
Proceedings: New Series, Vol. xxi., May, 1893, to May, 1894.
Royal 8vo. Boston, 1894.

Brussels. Société Royale Malacologique de Belgique.
Procès Verbal: Vol. xxi., pp. 75–86, Nov. and Dec., 1892.
Vol. xxii., pp. 1–92, Jan. and Dec., 1893.
Vol. xxiii., pp. 1–112, Jan. and Dec., 1894.
Vol. xxiv., pp. 1–84, Jan. and May, 1895.
8vo. Bruxelles, 1892–1895.

California. State Mining Bureau.
Twelfth Annual Report of the State Mineralogist, J. J. Crawford (Second Biennial). Two years ending September 15th, 1894. With Maps and Illustrations.
8vo. Sacramento, 1894.

Canada. Geological and Natural History Survey.
Annual Report for the years 1892–93. New Series, vol. vi., parts 3 and 4, with Plates and Maps. By A. R. C. Selwyn. 8vo. Ottawa, 1894.

——. Royal Society of Canada.
Proceedings and Transactions for 1894. Vol. xii. 4to. Ottawa, 1895.

Cincinnati. Society of Natural History.
Journal: Vol. xvii., Nos. 1–3, April to October, 1894.
Vol. xvii., No. 4, January, 1895. 8vo. Cincinnati, 1894–95.

Colorado. Scientific Society.
Proceedings: Vol. iv., 1891–1893. (Including Contents and Index.) 8vo. Denver, 1895.

——. Proceedings: (In separate pamphlets), viz.:
The Ore Deposits of Camp Floyd District, Tooele County, Utah. By R. C. Hills. Read August 6th, 1894.

A Suspected New Mineral from Cripple Creek. By F. C. Knight. Read October 1st, 1894.

Notes: On the Geology of the Western Slope of the Sangre De Cristo Range, in Costillo County, Colo. By E. C. and P. H. Van Diest. Read November 5th, 1894.

The Sampling and Measurement of Ore Bodies in Mine Examinations. By Edmund B. Kirby. Read December 3rd, 1894.

The Recent History and Present Status of Chemistry. By Prof. Charles S. Palmer. Read December 17th, 1894.

The Costilla Meteorite. By R. C. Hills. Read January 7th, 1895.

The Determination of Bismuth in Refined Lead and in Lead Bullion. By E. G. Eakins. Read February 4th, 1895.

The Non-existence of Cyanide of Zinc in Alkaline Solutions By N. Anderson. Read April 1st, 1895.

Vein Structure in the Enterprise Mine. By T. A. Rickard. Read April 1st, 1895.

The Volcanic Rock of Alum Hill, Boulder County, Colo. By C. Irving Andrews. Read June 3rd, 1895.
8vo. Denver, 1894–95

Colorado. Colorado College.
Studies: Fifth Annual Publication. Papers read before the Colorado College Scientific Society.
8vo. Colorado Springs, Colo., 1894.

Edinburgh Geological Society.
Transactions: Vol. vii., part 1. 8vo. Edinburgh, 1894.

Falmouth. Royal Cornwall Polytechnic Society.
Sixty-second Annual Report, 1894.
8vo. Falmouth, 1894.

Halifax. Geological and Polytechnic Society of Yorkshire.
Proceedings: New series, vol. xii., parts 4 and 5.
(With plates and map.)
8vo. Halifax, 1894–95.

——. "Boulder Clay Cliffs," Carr Naze, Filey. (Photograph.) By Rev. E. Maule Cole, M.A., F.G.S.
(Including Descriptive Pamphlet.)

Havre. Société Géologique de Normandie.
Bulletin: Tome xv. Annee. 1891.
Royal 8vo. Havre, 1893.

India. Geological Survey of India.
Records: Vol. xxvii., part 4, 1894.
(Including Title-page and Contents of vol. xxvii.)
Vol. xxviii., parts 1–3, 1895.
Royal 8vo. Calcutta, 1894–95.

——. Geological Museum, Calcutta.
An Introduction to the Chemical and Physical Study of Indian Minerals. Being a Guide to the Mineral Collection of the Museum. 8vo. Calcutta, 1895.

Iowa. Geological Survey.
Vol. ii., The Coal Deposits of Iowa. By Charles Rollin Keyes.
Vol. iii., Second Annual Report for 1893.
Imp. 8vo. Des Moines, Iowa, U.S.A., 1895.

Leicester Literary and Philosophical Society.
Transactions: New Quarterly Series.
Vol. iii., part 9, October, 1894.
Vol. iii., parts 10 and 11, January to April, 1895.
Vol. iv., part 1, July, 1895.
(Including Index, Title-page, and Rules for vol. iii.)
8vo. Leicester, 1894–95.

Liverpool Geological Association.
Journal: Vol. xiv., Session 1893–94.
8vo. Liverpool, 1894.

London. British Association for the Advancement of Science.
Report of the Sixty-fourth Meeting, held at Oxford in August, 1894. 8vo. London, 1894.
Report of the Corresponding Societies' Committee, Oxford Meeting, 1894. 8vo. London, 1894.

——. Geological Society of London.
List: November 1st, 1894. 8vo. London, 1894.
Quarterly Journal: Vol. l., part 4, No. 200, November, 1894.
Vol. li., parts 1–3, Nos. 201–203, Feb. to August, 1895.
8vo. London, 1894–95.

——. Geologists' Association.
Proceedings: Vol. xiii., part 10, November, 1894.
Vol. xiv., parts 1–4, February to August, 1895.
8vo. London, 1894–95.

——. London, Edinburgh, and Dublin Philosophical Magazine.
Series v., vol. xxxviii., Nos. 234 and 235, Nov. and Dec., 1894.
Series v., vol. xxxix., Nos. 236–241, January to June, 1895.
(Including Index and Title-page to vol. xxxix.)
Series v., vol. xl., Nos. 242–245, July to October, 1895.
8vo. London, 1894-95. *Purchased.*

——. Mines. Report of C. Le Neve Foster, H.M. Inspector of Mines for the North Wales, &c., and Isle of Man District, for the year 1894. Metalliferous and Slate Mines Act.
Folio. London, 1894.
[Presented by Dr. C. Le Neve Foster.]

London. Mines. Summaries of the Statistical Portion of H.M. Inspectors' Reports of Mines, 1894. Coal and Metalliferous Mines Acts. Folio. London, 1895.
[Presented by Dr. C. Le Neve Foster.]

——. Mines. List of Plans of Abandoned Mines, deposited in the Home Office, including plans transferred from the late "Mining Record Office." 4to. London, 1895.

——. Palæontographical Society.
Vol. xlviii. for 1894. 4to. London, 1894. *Purchased.*

——. Royal Society.
Proceedings: Vol. lvi., Nos. 338 and 339, November, 1894.
Vol. lvii., Nos. 340–346, January to June, 1895.
(Including Index and Title-page to vol. lvii.)
Vol. lviii., Nos. 347–351, July to October, 1895.
8vo. London, 1894–95.

Manchester. Geographical Society.
Journal: Vol. ix., Nos. 10–12, October to December, 1893.
(Including Index and Title-page for vol. ix.)
Vol. x., Nos. 4–9, April to September, 1895.
8vo. Manchester, 1893–95.

——. Geological Society.
Transactions: Vol. xxiii., parts 1–9, Session 1894–95.
(Including Index to vol. xxii.)
8vo. Manchester, 1894–95.

Milwaukee. Public Museum.
Twelfth Annual Report, Sept. 1st, 1893, to Aug. 31st, 1894.
8vo. Milwaukee, Wisconsin, 1894.

Minnesota. Academy of Natural Sciences.
Occasional Papers: Vol. i., No. 1.
Preliminary Notes on the Birds and Mammals Collected by the Menage Scientific Expedition to the Philippine Islands. By Frank S. Bourns and Dean C. Worcester.
Royal 8vo. Minneapolis, 1894.

Newcastle-upon-Tyne. North of England Institute of Mining and Mechanical Engineers.
Transactions: Vol. xliii., parts 5 and 6. Issued Sept., 1894.
Vol. xliv., part 1. Issued November, 1894.
Vol. xliv., parts 2–4. Issued Jan. to May, 1895.
Royal 8vo. Newcastle-upon-Tyne, 1894–95.

——. Annual Reports, 1893–94 and 1894–95.
Royal 8vo. Newcastle-upon-Tyne, 1894.

——. Report of the Proceedings of the Flameless Explosives Committee. Part 1, Air and Combustible Gases. By A. C. Kayll. Royal 8vo. Newcastle-upon-Tyne, 1894.

New South Wales. Department of Mines.
Records of the Geological Survey: Vol. iv., part 2, 1894.
Vol. iv., part 3, 1895.
4to. Sydney, 1894–95.

——. Royal Society of New South Wales.
Journal and Proceedings: Vol. xxviii., 1894.
(Including Index.) 8vo. Sydney, 1895.

New York. American Geographical Society.
Bulletin: Vol. xxvi., No. 4, 1894.
Vol. xxvi., No. 4, part 2, 1894.
(Including Title-page and Contents of vol. xxvi.)
Vol. xxvii., Nos. 1 and 2, 1895.
8vo. New York, 1894–95.

——. Academy of Sciences (late Lyceum of Natural History).
Transactions: Vol. xiii., October, 1893, to June, 1894.
Royal 8vo. New York, 1894.
Annals: Vol. viii., No. 5, February, 1895.
(Including Index and Title-page to Vol. vii.)
Royal 8vo. New York, 1895.

New Zealand. Department of Mines.
Reports and Papers relating to Minerals and Mining.
Folio. Wellington, New Zealand, 1894.

Nova Scotian Institute of Science.

Proceedings and Transactions: Second Series, Vol. i., part 3, of Session 1892–93. 8vo. Halifax, N. S., 1893.

North Carolina. Elisha Mitchell Scientific Society.

Journal: Vol. xi., parts 1 and 2, January to December, 1894. 8vo. Raleigh, N. C., 1894.

Paris. École des Mines.

Annales des Mines: Série ix., tome vi., liv. 10–12, 1894.
" " " " " vii., liv. 1–6, 1895.
" " " " " viii., liv. 7–9, 1895.
8vo. Paris, 1894–95.

Philadelphia. Academy of Natural Sciences.

Proceedings: Parts 2 and 3, April to December, 1894. (Including Index and Title-page to vol. for 1894.)
" Part 1, January to March, 1895.
8vo. Philadelphia, 1894–95.

——. American Philosophical Society.

Proceedings: Vol. xxxii., No. 143, May, 1893. (Including Index to vol. xxxii.)
" Vol. xxxiii., Nos. 145 and 146, June to December, 1894. (Including Index and List for vol. xxxiii.)
" Vol. xxxiv., No. 147, January, 1895.
8vo. Philadelphia, 1893–95.

Transactions: Vol. xviii., New Series, part 2.
4to. Philadelphia, 1895.
(Containing Article 2, "The Mammalia of the Deep River Beds." By W. B. Scott. Article 3, "The Classification of the Ophidia." By E. D. Cope. Illustrated.)

——. Wagner Free Institute of Science.

Transactions: Vol. iii., part 3, March, 1895.
Imperial 8vo. Philadelphia, 1895.

Pisa. Societá Toscana di Scienze Naturali.

Processi Verbali: Vol. ix., pp. 133–241, Nov. 1894, to March, 1895.
Royal 8vo. Pisa, 1894–95.

Plymouth. Plymouth Institution and Devon and Cornwall Natural History Society.
Report and Transactions for 1893–94. Vol. xi., part 4.
8vo. Plymouth, 1894.

Sweden. Geological Institution (University of Upsala).
Bulletin: Vol. i., No. 1, 1892.
Vol. ii., part 1, No. 3, 1894.
Royal 8vo. Upsala, 1892–94.

Truro. Royal Institution of Cornwall.
Journal: Vol. xii., part 1, 1894.
(Including Index and Title-page for vol. xi.)
8vo. Truro, 1895.

United States. Department of the Interior. Geological Survey.
Bulletin: No. 97.—The Mesozoic Echinodermata of the United States.
No. 98.—Flora of the Outlying Carboniferous Basins of South-western Missouri.
No. 99.—Record of the North American Geology for 1891.
No. 100.—Bibliography and Index of the Publications of the Geological Survey, with the Laws Governing their Printing and Distribution.
No. 101.—Insect Fauna of the Rhode Island Coal-field.
No. 102.—A Catalogue and Bibliography of North American Mesozoic Invertebrata.
No. 103.—High Temperature Work in Igneous Fusion and Ebullition, chiefly in relation to Pressure.
No. 104.—The Glaciation of the Yellowstone Valley, North of the Park.
No. 105.—The Laramie and the Overlying Livingston Formation in Montana.
No. 106.—The Colorado Formation and its Invertebrata Fauna.

United States. Department of the Interior. Geological Survey—
Bulletin: No. 107.—The Trap Dikes of the Lake Champlain Region.
No. 108.—A Geological Reconnoissance in Central Washington.
No. 109.—The Eruptive and Sedimentary Rocks on Pigeon Point, Minnesota, and their Contact Phenomena.
No. 110.—The Palæozoic Section in the vicinity of Three Forks, Montana.
No. 111.—Geology of the Big Stone Gap Coal-field of Virginia and Kentucky.
No. 112.—Earthquakes in California in 1892.
No. 113.—Report of Work done in the Division of Chemistry during the Fiscal years 1891–92 and 1892–93.
No. 114.—Earthquakes in California in 1893.
No. 115.—A Geographic Dictionary of Rhode Island.
No. 116.—A Geographic Dictionary of Massachusetts.
No. 117.—A Geographic Dictionary of Connecticut.
No. 118.—A Geographic Dictionary of New Jersey.
No. 119.—A Geological Reconnoissance in Northwest Wyoming.
No. 120.—The Devonian System of Eastern Pennsylvania and New York.
No. 121.—A Bibliography of North-American Palæontology, 1888–1892.
No. 122.—Results of Primary Triangulation.
8vo. Washington, 1894.

United States. Monographs: Vol. xix., The Penokee Iron-bearing Series of Michigan and Wisconsin. By R. D. Irving and R. Van Hise. 1892.
Vol. xxi., Tertiary Rhynchophorous Coleoptera of the United States. By S. H. Scudder. 1893.

Vol. xxii., A Manual of Topographic Methods. By H. Gannett. 1893.

Vol. xxiii., Geology of the Green Mountains in Massachusetts. By Raphael Rumpelly, J. E. Wolff, and T. Nelson Dale. 1894.

Vol. xxiv., Mollusca and Crustacea of the Miocene Formations of New Jersey. By Robert Parr Whitfield. 1895. 4to. (Illustrated.) Washington, 1892–95.

———. Statistical Papers: Mineral Resources of the United States, years 1892–93. By David T. Day.
8vo. Washington, 1894.

Report.—Twelfth Annual Report, 1890–91. By J. W. Powell, Director. 2 parts. Part 1, Geology. Part 2, Irrigation. Part 1 contains Reports by J. W. Powell, &c., also the following papers—"The Origin and Nature of Soils," by N. S. Shaler; "The Lafayette Formation," by W. J. McGee; "The North American Continent during Cambrian time," by C. D. Walcott; "The Eruptive Rocks of Electric Peak and Sepulchre Mountain, Yellowstone National Park," by J. P. Iddings. Part 2, "Report upon the Location and Survey of Reservoir Sites during the Fiscal year ended June 30th, 1891." By A. H. Thompson.
4to. Washington, 1891.

Report.—Thirteenth Annual Report, 1891–92. By J. W. Powell, Director. 3 parts. Part 1 contains Report of J. W. Powell, &c. Part 2, the following Papers—"Second Expedition to Mount St. Elias," by J. C. Russell; "The Geological History of Harbors," by N. S. Shaler; "The Mechanics of Apalachian Structure," by Bailey Willis; "The Average Elevation of the United States," by Henry Gannett; "The Rensselaer Grit Plateau in New York," by T. N. Dale; "The American Tertiary Aphidæ," by S. H. Scudder. Part 3, "Water Supply for Irrigation," by F. H. Newell; "American Irrigation Engineering," by Herbert M. Wilson; "Report upon the Construction of Topographic Maps, and the Selection and Survey of

Reservoir Sites in the Hydrographic Basin of the Arkan[illegible] River, Colorado," by A. H. Thompson; "Report upon t[illegible] Location and Survey of Reservoir Sites during the Fis[illegible] year ending June 30th, 1892," by A. H. Thompso[illegible] 3 parts. 4to. Washington, 1892.

Report.—Fourteenth Annual Report, 1892-93. By J. W[illegible] Powell, Director. 2 parts. Part 1 contains Report [illegible] J. W. Powell. Part 2, accompanying papers—"Potab[illegible] Waters of Eastern United States," by W. J. McGee "Natural Mineral Waters of the United States," by A. C[illegible] Peale; "Results of Stream Measurements," by F. H[illegible] Newell; "The Laccolitic Mountain Groups of Colorado, Utah, and Arizona," by Whitman Cross; "The Gold-Silver Veins of Ophir, California," by Waldemar Lindgren; "Geology of the Catootin Belt," by Arthur Keith; "Tertiary Revolution in the Topography of the Pacific Coast," by J. S. Diller; "The Rocks of the Sierra Nevada," by H. W. Turner; "Pre-Cambrian Igneous Rocks of the Unkar Terrane, Grand Canyon of the Colorado, Arizona," by Charles D. Walcott; "Notes on the Petrographic Character of the Lavas," by J. P. Iddings; "On the Structure of the Ridge between the Taconic and Green Mountain Ranges in Vermont," by T. Nelson Dale; "The Structure of Monument Mountain in Great Barrington, Massachusetts," by T. Nelson Dale; "The Potomac and Roaring Creek Coalfields in West Virginia," by Joseph D. Weeks. 2 parts. 4to. Washington, 1894.

United States. Geologic Atlas of the United States.
Nos. 1-6 and 8-12 folios. Washington, 1894.

Victoria. Department of Mines.

Reports: Special Reports on the Victorian Coalfields. By James Stirling (Assistant Geological Surveyor).
Folio. Melbourne, 1895.

Reports: Special Report on the Loss of Gold in the Reduction of Auriferous Veinstone in Victoria. By Henry Rosales, M.E., F.G.S. Folio. Melbourne, 1895.

Victoria. Department of Mines.

Reports: Annual Report of the Secretary for Mines. Including Reports on the working of part 3 of Mines Act 1890, Diamond Drills, &c., &c., &c., during the year 1894. Folio. Melbourne, 1895.

Vienna. K.K. Geologischen Reichsanstalt.

Verhandlungen: Nos. 10–18, 1894.

(Including Title-page and Index for vol. 1894.

„ „ Nos. 1–9, 1895.)

Royal 8vo. Wein, 1894–95.

Washington. Smithsonian Institution.

Annual Report of the Board of Regents to July, 1892. 8vo. Washington, 1893.

Annual Report of the Board of Regents to July, 1893. 8vo. Washington, 1894.

Annual Report of U.S. National Museum to June 30th, 1891. 8vo. Washington, 1892.

Annual Report of U.S. National Museum to June 30th, 1892. 8vo. Washington, 1893.

II. GEOLOGICAL AND MISCELLANEOUS PUBLICATIONS.

Presented by the Authors or other Donors.

Cooke, J. P. Biographical Notice. Addresses in Commemoration of Josiah Parsons Cooke, LL.D., late President of the American Academy of Arts and Sciences. Delivered 12th December, 1894.

[Presented by Mrs. Josiah Parsons Cooke.]

Collins, J. H. Presidential Address. Delivered at the Fourth Annual General Meeting of the Institution of Mining and Metallurgy, 20th March, 1895. 8vo. London, 1895.

[Presented by the President, J. H. Collins, F.G.S.]

On the Origin and Development of Ore Deposits in the West of England. By J. H. Collins, F.G.S. 8vo. Truro, 1895.

[Presented by the Author.]

Enys, J. S. Remarks on the Intensity and Quantity of the Junction Changes of Sussex and Cornwall, considered as Mining Districts. By J. S. Enys.
[Presented by J. D. Enys, F.G.S.]

Liversidge, A. Notes on some Australasian and Other Stone Implements. Read before the Royal Society of New South Wales, December 5th, 1892. By A. Liversidge, M.A., F.R.S. (With Plates.) 8vo. Sydney, 1892.
[Presented by the Author.]

Boleite, Nantokite, Kerargyrite, and Cuprite, from Broken Hill, New South Wales. With Plate. By A. Liversidge, M.A., F.R.S. 8vo. Sydney, 1894.
[Presented by the Author.]

Smyth, H. W. Notes of a Journey on the Upper Mekong, Siam. By H. Warington Smyth. With Maps and Illustrations. Royal 8vo. London, 1895.
[Presented by the Author.]

Worth, R. N. Early Days in South Molton. [Read at South Molton, August, 1894. By R. N. Worth, F.G.S.] 8vo. 1894.

Residents in the "Three Towns" in 1522–23. [Read at South Molton, August, 1894. By R. N. Worth, F.G.S.] 8vo. 1894.

The Stone Rows of Dartmoor. Part iii. [Read at South Molton, August, 1894. By R. N. Worth, F.G.S. 8vo. 1894.
[The last three presented by the Author.]

CURATOR'S REPORT.

During the past year the following specimens have been added to the Society's Museum:

NAME AND LOCALITY.	DONOR.
Radiolarian Chert—	
From Barracadoes Quarry, St. Stephen's Down, Launceston	Howard Fox, Esq.
From Fire Beacon Point, Boscastle	
From Pillaton, 5 miles N.W. of Saltash	
Specimens of chert from the Lower Arenig, Llanvirn, and Lower Llandeilo Series of St. David's, Pembrokeshire, associated with graptolites	F. J. Stephens, Esq.
Graptolites from Porthallow district, Cornwall—	F. J. Stephens, Esq.
Monograptus gregarius (Lapw.), Upper Llandovery	
Climacograptus normalis (Lapw.), Upper and Lower Llandovery	
Climacograptus tubiliferus, Upper Bala	
Climacograptus styloideus, Upper Bala	
Diplograptus foliaceus, var. vulgatus, Upper and Lower Bala	
Climacograptus antiquus (Lapw.), Upper Llandeilo	
Didymograptus—	
Comp. superstes (Lapw.), Lower Llandeilo	
Identified by Professor Lapworth, 1895.	

Mr. Collins has continued his Catalogue of the Cornish Fossils, originally collected by Mr. Peach, up to No. 582. So many of the fossils have been fixed on tablets and catalogued, while about an equal number have been similarly fixed to facilitate their study as a preliminary to naming, as well as for their preservation.

TREASURER'S STATEMENT, 1894-1895.

The Treasurer in Account with the Royal Geological Society of Cornwall.

Dr.	£	s.	d.
November 2nd, 1894—			
To Balance	65	1	3
November 8th, 1895—			
,, Ordinary Subscriptions and Arrears	70	7	0
,, Donation per H.R.H. The Prince of Wales	20	0	0
,, One Year's Dividend on £1500 Midland Railway 3% Debenture Stock, less tax	43	10	0
,, Howard Fox, towards Cost of Plates	3	0	0
,, Transfer from Departmental Account to meet Expenditure (Extraordinary), for which this fund is provided	60	5	7
	£262	3	10
,, Balance	7	12	10

Cr.	£	s.	d.
November 8th, 1895—			
By Rates and Taxes	0	8	0
,, P.P. Buildings for Housekeeper to Christmas, 1894	6	10	0
,, Geological Housekeeper to Michaelmas, 1895	15	0	0
,, Curator's Salary	50	0	0
,, Insurance Premium	2	12	9
,, Brendon (Printing *Transactions*)	57	15	7
,, Books, Binding, &c.	19	18	10
,, Expenses per Treasurer and Secretary, viz.— Advertising, Stationery, Printing, Gas, Postages, &c.	25	6	6
,, Repairs to Buildings	9	11	3
,, Alterations to Housekeeper's Rooms	66	7	1
,, Palæontographical Society	1	1	0
,, Balance	7	12	10
	£262	3	10

RICHARD F. BOLITHO,
Treasurer pro tem.

PENZANCE, *November 8th, 1895.*

LIST OF PAPERS READ AT THE ANNUAL MEETING,

8th November, 1895.

1. The Radiolarian Cherts of Cornwall. By Howard Fox, F.G.S.

2. Supplementary Notes on the Cherts and Associated Rocks of Roundhole Point, Cataclews Point, and Dinas Head. By Howard Fox, F.G.S.

3. Notes on Cornish Fossils. By J. H. Collins, F.G.S.

4. Some Geological Notes for 1895. By Francis J. Stephens.

THE RADIOLARIAN CHERTS OF CORNWALL.

By Howard Fox, F.G.S.

With Notes and Sketches by Miss Gulielma Lister,
And Notes by G. J. Hinde, Ph.D., F.G.S.

(Read November 8th, 1895.)

Introduction.
Southern Horizon.
Map.
Mullion Island.
Chypons Valley. Mullion.
Porthallow District. St. Keverne.
Pendower Beach. } Veryan.
Portloe. }
Percunning Cove. } St. Goran.
Great Peraver. }
Inland Exposures.
Mevagissey District.
Change in Character of Cherts as they occur Eastward.
Effect of deformation in changing form of Radiolaria, or destroying evidence of their former existence.
Association with Ordovician Rocks.
Association with Greenstone.
Northern, or Lower Culm, Horizon.
Map.
Extension of Cherts.
Position of Cherts in Culm Measures.
Porth, St. Columb.
Conclusion.
Explanation of Plates—
Plate i. Figs. 1-10.
Plate ii. Figs. 11-18.

During the past three years two well-marked horizons of radiolarian cherts have been observed in Cornwall, one in the south, the other in the north and east of the county. The southern horizon is in Ordovician (Lower Silurian) rocks; the northern or Lower Culm horizon is at the base of the Carboniferous rocks. Thus two "datum lines or horizons of reference" are established, between

which lie the Silurian and Devonian rocks of the county.

The southern horizon is composed of cherts and cherty shales, mostly black, containing radiolaria interbedded with shales and limestone, and generally associated with greenstone. These cherts occur in their purest and most typical form in Mullion Island. On the mainland they are found at intervals from Chypons Valley, one mile north-east of Mullion village, for twenty-five miles in a north-easterly direction, to Tolcarne, north of St. Michael Caerhayes. They are associated with the Ordovician quartzites of Porthallow, Veryan, and St. Goran.

The northern or Lower Culm horizon extends from Fire Beacon Point, one mile north of Boscastle, in an E.S.E. direction to the Tamar, both north and south of Launceston, with detached outliers at Pillaton and Painter's Cross, four to five miles N.N.W. of Saltash.

It is composed of black, grey, and bluish-grey cherty rocks, with a few lighter bands, and occasionally of light-tinted banded very hard siliceous rock with interbedded soft grey shaly beds, which are crowded with radiolaria and sponge spicules.

The full description of these rocks and the localities in which they occur, together with notes and sketches of such of the radiolaria as show the best structure, has appeared elsewhere.*

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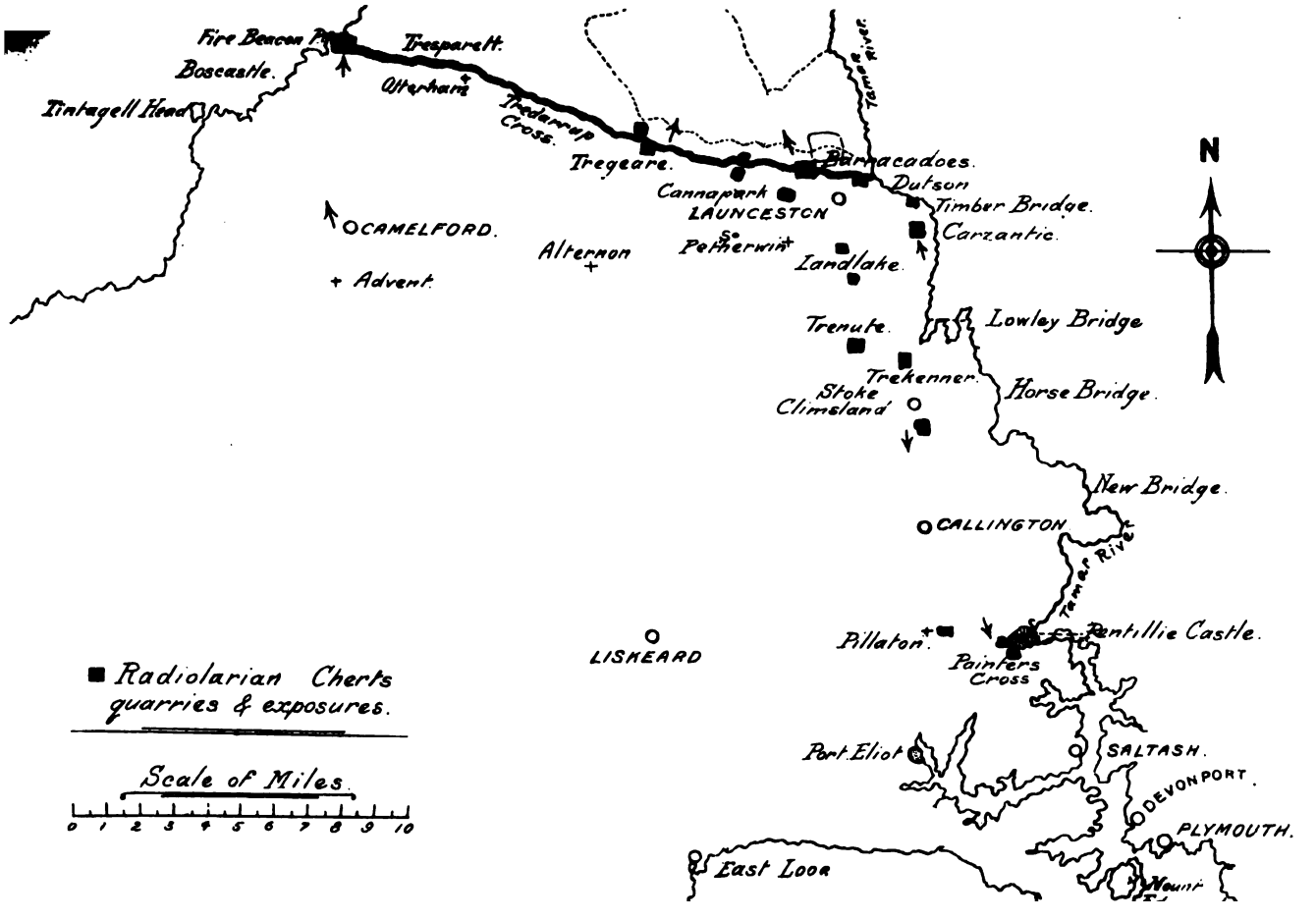
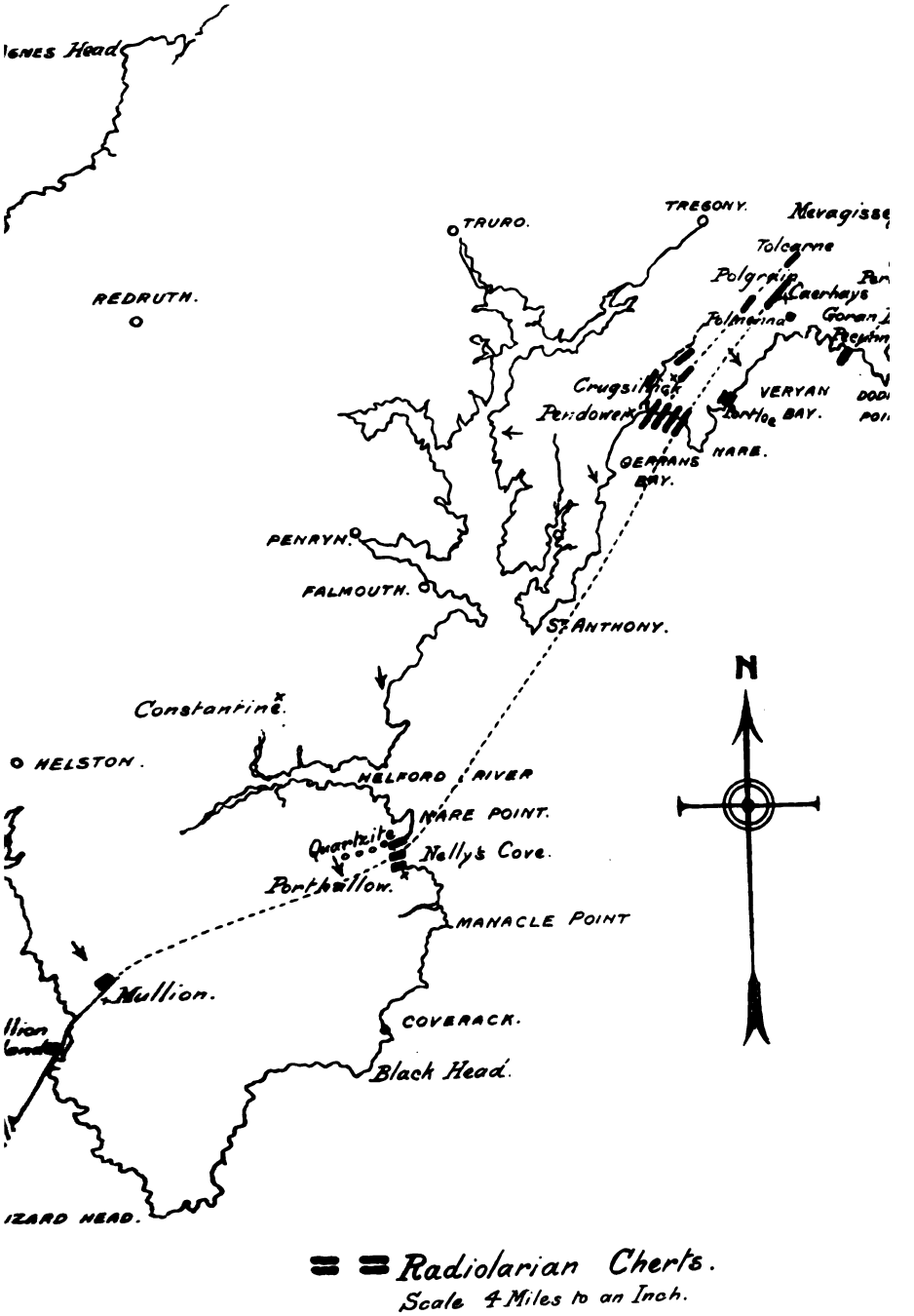
* "On a Radiolarian Chert from Mullion Island." By Howard Fox and J. J. H. Teall, F.R.S. *Q. J. G. S.* vol. xlix. (1893), pp. 211–220.


Fire Beacon Pt.
Trespare Ht.
Boscastle.
Otterham
Tintagell Head
Treburrup Cross
Tregeare.
Tamar River
Barnacadoes.
Dutson
Timber Bridge.
Cannapark
LAUNCESTON
Carzantic.
CAMELFORD.
Alternon
Petherwin
Landlake.
+ Advent
Trenute.
Lowley Bridge
Trekenner.
Stoke Climsland
Horse Bridge.
New Bridge.
CALLINGTON
Tamar River
LISKEARD
Pillaton.
Pentillie Castle.
Painters Cross
Port Eliot
SALTASH.
DEVONPORT.
PLYMOUTH.
East Looe
N
Radiolarian Cherts quarries & exposures.
Scale of Miles.
0 1 2 3 4 5 6 7 8 9 10


Agnes Head
REDRUTH.
TRURO.
TREGONY.
Mevagissey
Tolcarne
Polgrain
Caerhays
Polmeina
Crugsillick
Perdowen
VERYAN
Portloe
BAY.
NARE.
GERRANS BAY.
PENRYN.
FALMOUTH.
St ANTHONY.
Constantine.
NELSTON.
HELFORD RIVER
NARE POINT.
Quartzite
Nelly's Cove.
Porthallow.
MANACLE POINT
Mullion.
COVERACK.
Black Head.
LIZARD HEAD.
N
= = Radiolarian Cherts.
Scale 4 Miles to an Inch.

The object of the author is to give a brief abstract of these papers, and to complete the record of what has been done up to the present time as far as the county of Cornwall is concerned.

MULLION ISLAND.

The western extremity of this southern horizon is found in Mullion Island and its outlying rocks. The island is composed of greenstone of a marked spherical or ellipsoidal structure, in which thin beds of chert and shale are seen at different horizons from the foreshore to the summits of the northern and south-eastern promontories. Some lenticles of limestone occur in the greenstone close to the shales and cherts, but their respective relations are obscure. The beds of chert vary from half an inch to nine inches in thickness. They are generally traversed by a network of white quartz veins. The chert varies in colour from black to grey or brown, and the thinner layers frequently have a central dark band bordered by lighter-coloured margins, in which the casts of radiolaria can be seen with a pocket lens as minute round spots. On the upper surfaces of some of the layers of chert, where the shale has been removed by the weather, the radiolarian casts

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"On the Radiolarian Cherts of Cornwall." By HOWARD FOX. *Brit. Assn. Report*, 1893, pp. 771–2.

"On Greenstones Associated with Radiolarian Cherts." By J. J. H. Teall, F.R.S., *Trans. R. Geol. Soc. Cornwall*, vol. xi. pp. 560–565.

"On a Well-marked Horizon of Radiolarian Rocks in the Lower Culm Measures of Devon, Cornwall, and West Somerset." By G. J. HINDE, PH.D., and HOWARD FOX. *Q. J. G. S.* vol. li. (1895), pp. 609–668.

appear as rounded protuberances, like so many millet seeds thickly covering the rock. When these protuberances are placed under the microscope, the lattice-like structure of the test can in many cases be clearly seen. From microscopic slides of these cherts Dr. Hinde identified and figured* several genera of radiolaria. The plates accompanying the present paper give sketches of radiolaria from other slides, kindly made for me by Miss Gulielma Lister, of Lyme Regis, some of which Dr. Hinde has also been able to identify generically. The small beaches in the northern bay of the island are covered with chert pebbles. Dr. Hinde thus describes a section of one of them.

Slide 601. *Mullion Island Pebble.*

"This is a fairly typical section of the Mullion Island chert. The rock is of the usual cryptocrystalline silica with a varying amount of dark very finely granular material. It is traversed in all directions by veins and strings of quartz—some simple, straight, and comparatively wide; others give off lateral branches which run nearly parallel with the parent vein. In others again the direction is crooked, or even zigzag.

"The rock is filled with the fairly clear casts of radiolaria. These are mainly circular or oval forms of *Cenosphæra* and *Cenellipsis;* in a few instances a single radial spine projects from the sphere, *Dorysphæra.* Occasionally faint traces of structure

* *Q. J. G. S.* vol. xlix. Pl. 4.

are shown in the alternate light and dark spaces of the borders of the sections."

The only exposure of chert not indicated in the map of Mullion, published in the *Quarterly Journal*,* is one lately observed on the foreshore of the eastern side of the island.

CHYPONS VALLEY.

In 1894 Mr. F. J. Stephens found a large block of chert on Clahar Cairn, 1200 yards N.N.E. of Mullion village. Subsequently several blocks were found lying on the surface in Chypons Valley, 500 yards further north, and many more are built into the hedges. The exposures from which they must have been quarried appear to have been overgrown or covered with rubbish. Sections of this rock show only faint indications of radiolaria. Chypons Valley is exactly where the map of the Geological Survey shows the slate to join the schist series. A fault probably runs down this valley through La Frowder to Polurrian, and curving somewhat to the south continues its course between Mullion Island and the mainland.†

PORTHALLOW DISTRICT.

During Easter, 1893, Mr. Teall and Prof. Lapworth visited Cornwall, and I had the pleasure of accompanying them throughout the Lizard district, from Trewavas Head on the west to Helford River on the east.

On rounding the point from Porthallow to Nelly's

* *Q. J. G. S.* vol. xlix. p. 212.

† See *Q. J. G. S.* vol. xlix. p. 215.

Cove we saw greenstone weathering in the same spherical form as that of Mullion Island. On the foreshore are the well-known fossiliferous bands of limestone, whilst interbedded with dark shale in the foreshore, near high-water mark, are found thin bands of chert, much crushed and contorted. Bands of chert can be traced in places halfway up the cliff, and the fields above are strewn with angular fragments of black chert. The upper part of the beach is covered with black chert pebbles, veined with quartz. Microscopic sections of these pebbles show them to be full of casts of radiolaria, with occasional indications of structure, whilst sections of the chert *in situ* show that the rock has been subject to such an amount of crushing as to destroy all traces of radiolaria. The shearing appears to have affected the rock before the veins were formed. The foreshore and cliffs for the next 800 yards, between Nelly's Cove and Ligwrath Point, are frilled at intervals with thin beds of chert and shale. Sections from some of these beds of chert show numerous casts of radiolaria with no shearing.

At Ligwrath Point the "conglomerates" and quartzites are seen, in which latter Mr. J. H. Collins and Mr. Thos. Clarke found Ordovician fossils.*

Mr. F. J. Stephens informs me that he has found a fragment of radiolarian chert in the "conglomerate" west of Nare Head, Helford River. He has moreover been fortunate enough to discover graptolites in the dark shales interbedded with these cherts.

* *Trans. R. Geol. Soc. Corn.* vol. x. p. 51.

FIG. I.

CLIFF. WEST PENDOWER BEACH.

a = "HEAD." *b* = RAISED BEACH. *c* = CHERT.

PENDOWER BEACH.

At the west end of this beach ("Creek Stephen" of the one-inch map), in the parish of Veryan, seven miles N.E. of Falmouth, there are some very interesting exposures. Black chert is seen interbedded with shales on the foreshore, and it also forms the base of the cliff. Above the shales and cherts a raised beach is seen, and above this raised beach the chert in two places continues to the top of the cliff. The base of the cliff is occasionally composed of compact chert several feet thick, at other times of chert sheared into thin bands, which are more or less disturbed. (Plate 1.) The raised beach has numerous angular fragments of quartz, chert, and shale, as well as pebbles of the same rocks, in its lower beds; the upper beds are composed mainly of black, red, and brown sand, the whole cemented together by oxide of iron. This raised beach varies from 5 to 8 or 10 feet in height. Above the raised beach, for many hundred yards to the eastward, a "head" from 20 to 50 feet in height is seen, composed of loam and sand, and containing occasional angular fragments of quartz, chert, and shale. In one place in the base of the cliff the chert appears to pass into quartz. Black chert occurs at intervals in the foreshore and cliff for more than one thousand yards eastward, until we reach the well-known quartzites of Carne, in which Ordovician fossils were first found by Mr. Peach.*

* *Trans. Geol. Soc. Corn.* vol. vi. pp. 321-2; vol. vii. p. 25, 300-8.

Numerous Brachiopoda of Caradoc age are still to be found in a few of the less compact blocks of quartzite which cover the foreshore. The general dip of the rocks on this coast is S.S.E. 40°, with considerable local disturbances. The chert beds vary from half an inch to several feet in thickness, and are interbedded with shales and limestone.

From the west end of Pendower Beach, in an easterly direction along the shore, the beds of limestone increase in thickness and frequency till, at Gidley Well, they form the marked feature of the coast, and are beautifully veined with quartz and calcite. The beds of chert, on the contrary, become thinner and less frequent. At and near Gidley Well they are so scattered as to be somewhat difficult to find. They also become more impure and more or less decomposed. Mr. Teall attributes this decomposition to the oxidation of pyrites crystals, which the microscope shows to be present in the chert.

Crinoidal remains are found in the dark shales interbedded with these cherts, but hitherto no zonal fossil has been recognised in them. Sections of the chert from this district show indications of radiolaria with marked signs of shearing.

PORTLOE.

The most interesting exposure of chert here is in Portloe Point, which bounds the cove on the east. Beds of chert, interbedded with more or less decomposed mudstone and shale, are found in the green-

stone tuff or breccia of the district (the "trappean conglomerate" of De la Beche). The bands of chert vary from half an inch to six inches in thickness, and extend over a space twenty yards in length by seven yards in extreme width, parallel with, and to the south-east of, a fault running N.E. and S.W. about high-water mark.

This exposure has an additional interest, from some of the bands of black chert appearing to pass into cloudy and finally clear quartz. Microscopic sections show strings and leaders of black chert in the quartz, with traces of radiolaria in the black bands. In one slice crystals of pyrites are seen, together with long straight bodies which do not show sufficient character for identification.

There are several other exposures of chert in and near the village of Portloe, extending from 500 to 600 yards due west of the Point. One of these is seen by the roadside on the eastern hedge of the entrance to Pine Cottage. The beds are here interbedded with shale, and the whole are much disturbed. Sections of these cherts show traces of radiolaria.

PERCUNNING, OR PECUNNEN, COVE.

Eastward of Portloe no coast exposure of chert has been observed till we reach Percunning Cove, immediately west of Hemmick, at the western base of the Dodman peninsula. Thin bands of more or less impure chert and chert breccia are found here in vertical friable dark shales, which also contain numerous bands and lenticles of black

quartzite and yellowish-grey limestone. These thin cherty bands are best seen to the west of the fault at the east end of the Cove. One slice of this rock shows numerous oval casts of radiolaria. Another slice shows a bluish shale with thin layer of quartz, also with patches of radiolarian rock crushed up with the shale.

GREAT PERAVER.

Two miles north-east of Percunning Cove, to the east of Dodman Point, on the southern cliff of Great Peraver, we find cherty rock similar to that of Percunning. One slice shows numerous circular and oval outline casts of radiolaria without structure. Another shows a bluish shale with thin layer of quartz, also with patches of radiolarian rock which have been crushed up with the shale. We failed to find any exposure of chert between Percunning and Great Peraver. Some beds in Treveague that had a chert-like appearance proved under the microscope to be phyllites. We failed also to find any further coast exposure of chert east of Great Peraver.

The keen eye of Sir H. de la Beche detected the similarity of the calcareous rocks at Nelly's Cove, Percunning, and Great Peraver, three of the localities in which radiolarian chert occurs. At page 95 of his "Report" he writes: "The quartz rock south of the Nare Point (Meneage) can be traced inland with a southern dip by Trewothack, Trezebal, and Trevaddra, towards St. Martin. To it succeed slates

in which there is calcareous matter, and even grey limestone in Betsey's Cove, north of Porthalla—beds corresponding with the calciferous slates of Hemmick Cove, in Veryan Bay, and the limestones of Gorran Haven."

INLAND EXPOSURES.

The best inland exposures of chert which we have hitherto seen are the following:

Crugsillick.—In the hedge 100 yards east of Crugsillick farm garden, 1500 yards N.N.E. of Pendower House, to the west of the stream.

In several places in the wood on the east side of the stream, south-west of Treburthes farm. The chert is exposed at intervals for a distance of 600 yards, say from 900 to 1500 yards N.N.E. of Crugsillick farmhouse.

Gwendra.—300 yards north of Pendower Beach, on both sides of the road which bounds Gwendra farmhouse on the north and east. The chert here is much broken and traversed by thin veins.

Pendower Beach Road.—On both sides of the road leading from Pendower Beach to Carne Beacon, at intervals for a distance of 300 yards from the beach. The beds of chert are thin and ferriferous, more or less decomposed, and interbedded with limestone and friable shales.

Veryan Village.—In the east hedge of the road which runs through the village from the south, both at the corner of the cross-roads and further down the hill behind the New Inn; also in the hedge at the left-hand of the carriage entrance to the rectory.

In this latter place the chert and shale are more or less decomposed.

Polcouta.—Three hundred yards north of the White Hart Inn; south of the bridge, in the eastern hedge. Thin bands of cherty shale are interbedded with limestone and shale. The microscope shows lenticles in this rock which probably represent deformed radiolaria.

Polgrain.—Six hundred yards W.N.W. of St. Michael's Church, Caerhayes. In descending this hill from the north we find massive limestone on our right-hand immediately south of the farm gate, whilst a few yards further down, at the bend of the road, the eastern hedge exposes beds of chert from one to three inches thick for about 30 feet distance. The chert is ferriferous, and more or less decomposed. About 40 yards further down in the same hedge thin beds of similarly decomposed chert are seen interbedded with thick beds of limestone in the shale. The microscope shows this chert, in one specimen, to have clear lenticular spaces which probably represent flattened radiolaria, and in another crowded circular casts.

Tolcarne Hill.—Tolcarne is about three-quarters of a mile north of St. Michael's Church, Caerhayes. In ascending the hill, to the west of the stream, we find chert in the north hedge of the public road, about 30 yards from the bottom of the hill, and about 18 inches from the foot of the hedge. It is associated with greenstone and shale. It has been subject to such a degree of shearing as to give it

a schistose appearance. It occurs in beds nearly two inches thick, black in colour, and interbedded with light-coloured shale. The vegetation prevents an examination of an extended surface. A section shows, under the microscope, black spots and clear round spaces which may without much fear of error be taken to represent radiolaria. A line drawn for five miles, from the chert in the west end of Pendower Beach, through the chert exposures in Veryan village and Polmenna, will exactly hit this Tolcarne exposure.

Lower Polmenna Hill.—Nine hundred yards S.W. of Tolcarne, and very much in the same horizon, in the west hedge of the hill to the north of the stream, some more or less decomposed chert is found. Under the microscope a section of this rock shows clear, round spaces similar to that from Tolcarne.

Caerhayes Castle Hill.—About three hundred yards due south of Caerhayes Castle, in the northern hedge of the public road, impure cherty rock occurs in which carbonates are present.

Portloe Village.—These exposures have been referred to amongst the coast sections.

MEVAGISSEY DISTRICT.

We expected to find an extension of these cherts between Chapel Point and Mevagissey, and still further east, but were unsuccessful.

Sections were cut from thin beds of compact rock which somewhat resembled chert, in the Mevagissey district, which Mr. Teall kindly examined. He thus

describes them: "These compact bands consist essentially of a carbonate of iron and manganese, the iron being largely in excess of the manganese. Lime and magnesia are present, but only as traces. Phosphoric acid is also present.

"The carbonate, which does not effervesce with cold acid, is a manganiferous siderite.

"Manganese is mined in the Arenig beds of Merionethshire. These bands of siderite probably mark a definite horizon. Their occurrence should therefore be carefully noted."

CHANGE IN CHARACTER OF CHERTS AS THEY OCCUR EASTWARD.

As we proceed eastward from Mullion Island the cherts become more or less impure. They are occasionally rather cherty shales than true cherts. They also contain a considerable amount of pyrites, often in idiomorphic crystals. This pyrites, by alteration, passes into ferric oxide. Carbonates are also present as the eastern limit is approached. The various stages of decomposition can be seen extremely well on Pendower Beach. At its western cliff the chert is black and compact. As we proceed east we find increasing signs of decomposition. There are, nevertheless, some thin, scattered, compact beds of chert throughout the entire district.

In Mullion Island the chert varies in colour from black to grey and brown, with the edges of some bands weathering white.

On the mainland the cherts are all black, unless

when they are more or less impure and decomposed, when they have a dark ochrous or ferruginous colour.

EFFECT OF DEFORMATION IN CHANGING THE FORM OF RADIOLARIA AND DESTROYING EVIDENCE OF THEIR FORMER EXISTENCE.

The cherts of this southern horizon have been subjected to great deformation from earth movements.

In Mullion Island the movement is seen to have taken place before the final consolidation of the cherts. Some layers have been pinched out, while others have been thickened into nodules. That these nodules are not of a concretionary character is shown by the presence of radiolaria. Mr. Teall writes: "I am puzzled to account for the nodules. They occur in the chert of the southern uplands of Scotland."

At Nelly's Cove, north of Porthallow, the sections cut from the chert *in situ* show veins of quartz and calcite, with marked signs of crushing in the quartz. All traces of radiolaria have disappeared, without doubt owing to the shearing which appears to have affected the rock even before the veins were formed. A few hundred yards north of Nelly's Cove sections of the chert show unmistakeable traces of radiolaria with no signs of shearing.

Nelly's Cove is strewn with pebbles of black chert veined with quartz. Sections of these pebbles show the casts of radiolaria to be very crowded, and some spined radiolaria, *Dorysphæra*, are also present. In

the Veryan and Caerhayes districts the cherts seldom show circular casts of radiolaria. In some cases the casts are oval; in more cases they appear to be flattened into lenticles, and in quite half the sections all traces of radiolaria have been crushed out of them.

In the Goran district some thin bands of chert show circular casts, and bluish shale from this locality is found to contain patches of radiolarian rock which have been crushed up with it.

The following list indicates the extent of deformation as we proceed from west to east:—

Mullion Island.—Of twenty sections five show structure, and only one fails to show casts of radiolaria.

Chypons Valley.—All the sections show numerous faint circular casts without structure.

Porthallow District.—All the sections except those from Nelly's Cove show traces of radiolaria. A pebble of chert from this cove shows spined radiolaria (*Dorysphæra*).

Veryan District.—Only one-third of the sections show traces of radiolaria; the others show much shearing.

St. Goran District.—The cherts here are so crushed that it is difficult to find any suitable for slicing. Half the specimens cut show radiolarian casts, and both at Percunning Cove and Great Peraver sections of bluish shale show patches of radiolarian rock crushed up with the shale.

ASSOCIATION WITH ORDOVICIAN ROCKS.

In the Porthallow, Veryan, and Goran districts we find a similar succession of rocks on the coast, dipping about S.S.E.

Proceeding in each locality from the south to the north we find arenaceous and argillaceous slates and shales, apparently overlaid by dark shales in which radiolarian cherts and limestones are interbedded, and these are overlaid by quartzites containing Ordovician fossils.*

Sir Henry De la Beche† considered this apparent succession in the Veryan district to be the true one. Prof. Sedgwick examined this district in 1852. He writes‡ as follows: "Along the shore of Gerrans Bay the blue killas is followed, to all appearance in ascending order, by a coarser arenaceous grauwacke, sometimes very ferruginous and decomposing. Over the preceding rocks comes a remarkable white quartzite, 30 or 40 feet thick, dipping nearly S.E.; and the quartzite is overlaid in its turn by earthy and ferruginous slates, by conglomerates almost passing into trap shale, and by very ferruginous beds of trap. . . . The section is *to all appearance* an ascending section, and we discovered no trace in the cliffs of any fault or break of continuity."

If the apparent succession be the real one, the cherts would appear to be older than the Caradoc quartzites. Mr. Teall informs me that in the

* *Trans. R. Corn. Geol. Soc.* vol. vi. p. 321.

† *Report Geol. Corn. Dev. and Som.* p. 84.

‡ *Q. J. G. S.* Feb. 1852, viii. p. 10.

southern uplands of Scotland the radiolarian cherts and shales are found below a Caradoc grit or conglomerate, which contains fragments both of the chert and shale. This is probably what occurs north of Porthallow.

Mr. F. J. Stephens has lately discovered graptolites in the shales which are interbedded with the radiolarian cherts of the Porthallow district. The specimens hitherto identified indicate a considerable range of beds. It is therefore premature to say more at present than that the radiolarian cherts of South Cornwall appear to have been formed in Ordovician times.

ASSOCIATION WITH GREENSTONE.

A very interesting fact connected with these radiolarian cherts has been noticed by Mr. Teall, in his paper published in the last volume of your *Transactions* (pp. 360–5).

He draws attention to the marked similarity between the spheroidal or bolster-like structure of the greenstone of Mullion Island, with that of the southern uplands of Scotland, of Saxony, and of California, with which radiolarian cherts are associated.*

The resemblance is not, however, confined to the spheroidal structure, but "extends also to micro-

* Since the publication of Mr. Teall's paper the jasper and the light-coloured rock from the Buri-buri Ridge, California, have been found by Dr. Hinde to be crowded with radiolaria. *Vide* "The Geology of Angel Island," by F. L. Ransome, with note by Dr. Hinde. *Univ. of California*, vol. i. no. 7, pp. 193–240. Plates 12–14.

scopic structure, composition, mode of alteration, and to the presence of amygdaloids. . . . It seems, therefore," he writes, "almost impossible to avoid the conclusion that the peculiar structures in question are in some way connected with the physical conditions under which the cherts accumulated." He suggests whether they may not be characteristic of submarine and possibly deep sea lavas.

NORTHERN OR LOWER CULM HORIZON.

The *Quarterly Journal of the Geological Society*, recently published, gives so full an account of the cherts of the northern or Lower Culm Horizon that a brief reference is alone needed here.

About a mile north of Boscastle, on the North coast of Cornwall, a prominent ridge of rocks forms the crest of Fire Beacon Point, 460 feet above sea level. It is a conspicuous object from Forrabury Church. There is a plateau of rock 30 yards long on the top where fire beacons were probably lit in olden times. The plateau and entire ridge are composed of black chert, occasionally banded with pale chert and traversed by numerous quartz veins in the same manner as the cherts from Mullion Island in the South of Cornwall. This mass of chert and cherty rock can be traced northwards for 200 to 300 yards on the slope of Beeny Cliff, to within 150–200 feet of the sea level, the lower beds becoming more shaly and gradually passing into the carbonaceous shales below. The chert exposed appears to be from 80 to 90 feet thick. The beds of chert

vary from half an inch to nine inches in thickness, and on the top of the hill are much folded and contorted. Some of the layers have been pinched out, as in the Mullion Island chert. These beds of chert with the shales above and below them, dip north at an average angle of about 25°, which is the prevailing dip of the district.

The microscope shows the dark bands of this chert to be impure, with little or no indication of radiolaria. The light bands, on the contrary, are often full of casts of radiolaria, although all trace of structure has disappeared.

There are but few quarries or other artificial exposures of chert *in situ* eastward of this locality for many miles, but the fields are strewn with angular fragments of this rock, some of which are several inches in diameter, and in many of these casts of radiolaria can be detected by a pocket lens. Some fields one mile E.N.E. of Fire Beacon Point are thickly covered with fragments of chert and shale up to the 750 feet level above the sea. The fields on the 800–900 feet level, a little further north, are just as thickly covered with fragments of grits and shales with no cherts, whilst those on the 600–750 feet level, between Fire Beacon Point and Otterham, four miles east of Boscastle, contain scattered blocks and fragments of chert in which radiolarian casts can be seen. Similar loose fragments are found at Tredarrup Cross, two miles further east. Three miles still further east, or nine and a quarter miles E.S.E. of Fire Beacon

Point, we find a quarry north of Tregeare Down Beacon, and two quarries immediately south of it, in which a considerable thickness of radiolarian chert is exposed. There are several quarries on either side the road which lead from these to Barracadoes Quarry, in St. Stephens, one mile north of Launceston, in all of which radiolaria can be seen.

The Barracadoes Quarry (marked "killas" on the six-inch map) is peculiarly interesting, as we find there a soft, white, shaly rock full of radiolaria and sponge spicules, interbedded with light-tinted, banded radiolarian hard chert. From this spot chert can be traced towards the Tamar, through a quarry about 700 yards W.S.W. of the village of Dutson, and another quarry north of Higher Goodmansleigh.

About one mile S.W. of Barracadoes Quarry there is a large disused and overgrown limestone quarry called Cannapark, now full of water. Carbonaceous shales are seen to overlie the limestone, whilst chert and shales occur on the top of all.

We have thus a fairly straight horizon of chert from Fire Beacon Point, in an east-south-easterly direction, to the Tamar, through the localities mentioned.

Dr. Holl, in his paper "On the Older Rocks of South Devon and East Cornwall,"* gives the result of his careful survey of the Culm Measures of East Cornwall. He draws attention to several exposures of chert south of Launceston, most of which prove on examination to be radiolarian in character. The

* *Q. J. G. S.* vol. xxiv. (1868), pp. 401–414.

most important of these is at Carzantic Quarry, about two miles E.S.E. of Launceston. Gordon Hill, of which this quarry exposes a section, appears to be composed of radiolarian chert. The quarry shows from 50 to 70 feet thickness of light and dark banded regularly-bedded chert, without any intervening beds of soft shales. It is impossible to say to what depth the chert beds continue below the section exposed. The casts of radiolaria are so numerous in some of the lighter-coloured beds as to be distinguished by the unaided eye. Dr. Hinde has, moreover, detected structure in some of the casts, and figured them.*

There is a disused and overgrown limestone quarry at Timber Bridge, on the Tamar, two miles due east of Launceston, where the same succession of rocks occurs as in the Cannapark Quarry and in many Devonshire quarries further east.

The line of junction between the Culm and Devonian rocks is given in the map of the Geological Survey as crossing the Tamar on the horizon of Lowly Bridge, four miles S.S.E. of Launceston. Dr. Holl, in addition to showing that the Culm Measures are to be traced in a north-west direction amongst the Devonian rocks for a varying width of from a quarter to over one mile, to within a short distance of Alternun, places the junction line two miles further south than the Survey map. His line crosses the Tamar at Horse Bridge, near the horizon of Tavistock. The radiolarian character of

* See *Q. J. G. S.* vol. li. (Nov. 1895), plate xxvi. figs. 1, 7, 10.

the cherts observed in this district confirms Dr. Holl's view, that they belong to the Culm series. A quarry in a field 300 yards east of Landlake Cross, nearly two miles south of Launceston, exposes radiolarian chert. The high ground from East Penrest to Trebollet, as pointed out by Dr. Holl, is composed of chert which proves to be filled with radiolarian casts, several of which show structure. This can be best examined at Trenute Quarry, near Trebollet, four miles south of Launceston, and at Trekenner Head, nearly a mile further east, where a disused and overgrown quarry has numerous blocks of chert lying about the surface. Dr. Hinde recognises four genera of radiolaria in a slice of chert from this quarry. The chert mentioned by Dr. Holl as exposed at the cross-roads north of Stoke Climsland can no longer be seen, but a few thin beds of radiolarian chert are found in the shale which composes the east hedge of the public road in the hill directly south of Stoke Climsland.

Dr. Holl indicates in his map two small outlying patches of the Culm Measures, about four and five miles N.N.W. of Saltash. Chert from this district near Painters (Penters or Pentre) Cross not only shows casts of radiolaria, but also indications of test structure as well. In addition to the exposures observed by Dr. Holl, there is a hog-backed hill two miles west of Painters Cross which, like Gordon Hill and other ridges in the neighbourhood of Launceston, appears to be composed of chert which is filled with radiolarian casts, many of which show

indications of structure. A quarry has been opened in this hill 500 yards due east of Pillaton Church, which exposes about twenty feet of beds of light and dark banded chert varying from one inch to nine inches in thickness. How much deeper it may occur in the ground cannot be ascertained. The beds are much contorted, and a fault runs through the quarry. This hill has a height of from 400 to 460 feet above sea level for a length of 600 yards and a width of 500 yards.

There are two quarries in the grounds of Pentillie Castle, on the Tamar, east of Painters Cross. One close to the castle, about 200 feet above sea level, shows the typical dark shales and thick beds of grit of the Culm Measures. The other, called the Ball Quarry, one and a half miles south-east of the castle, is close to the river and exposes soft pale slate or shale of the Devonian system.

POSITION OF THE RADIOLARIAN CHERTS IN THE CULM MEASURES.

Sir Henry De la Beche, in his *Report on the Geology of Cornwall, Devon, and West Somerset*, gives a section of the coast as seen from a boat outside Boscastle Harbour. This indicates the precise horizon where the Carboniferous rocks overlie the Devonian.

He writes (p. 106): "Proceeding now to the southern boundary-line of this system . . . we find that the upper series rests upon the lower near Boscastle, Cornwall, in a bay between the Meachard

Rock and Short Island. Here, though the one rests conformably upon the other, as represented, Plate 4, fig. 1, there is no passage of the one system into the other. On the contrary, there is a marked line between the carbonaceous slates and arenaceous rocks above and the clay-slates passing into roofing-slate beneath."

The normal dip of all the rocks in this district is fairly uniform, about 25° north. The crest of Fire Beacon Point, where the chert first comes in, is about one mile—say 1800 yards—due north of the horizon of the junction-line as laid down by De la Beche. This, at an angle of 25° for the dip, gives a thickness of about 750 yards between the extreme base of the Carboniferous rocks and the chert. The folding and contortions of these upper rocks are numerous, and in places extreme, but as a rule of small diameter. What proportion of this 750 yards we should deduct for extra thickness caused by this folding is a matter of pure hypothesis. If we take it at one-third, we shall have in the Boscastle district a thickness of 500 yards between the base of the Culm Measures and the incoming of the chert. That the folding is not on a large scale may be inferred from the chert appearing on no other part of the coast. As we proceed north, we find the rocks to consist of the typical grits and shales of the Culm Measures. The foldings and contortions increase in size and complexity, till we get the extraordinary sections for which the Northern Door and Millook are so notable.

PORTH. ST. COLUMB MINOR.

The beach near the bridge at Porth is strewn with black pebbles. Some of these, when sliced, prove to be chert containing radiolaria, in some of which the structure and the outlines of the spines are indicated. (*Vide* Plates I., II., figs. 1, 2, 3, 13, 14, 15, 16, 17, 18.)

A careful search of the adjoining coast and inland exposures has hitherto shown no chert *in situ*, and the question arises as to the geological position and locality of the beds from which these chert pebbles have been derived.

Dr. Hinde thus describes their microscopic character: "The sections from Porth are scarcely to be distinguished, in general character, from some of those which come from the Culm; for example, from Ashbrittle and from Blackpool Copse Quarry (near Dulverton), Somerset; and I think in this latter there are radiolaria with a single large spine, the same as shown in the Porth section. On the otber hand, the sections do not seem to me to correspond generally with Mullion Island chert; at all events, with such sections of it as I possess to compare with."

Most of our authorities now consider that the flints which are scattered over the surface of Cornwall are relics of the Cretaceous rocks which once covered the county. So the question arises whether these Porth pebbles may not be the relics of Culm beds long since denuded. We have not yet had an

opportunity of visiting the outlying islands on the north coast of Cornwall. They may throw light on the matter.

CONCLUSION.

The not inconsiderable thickness of the cherty rocks which occur along the line of the southern outcrop of the Culm Measures, from near Boscastle eastwards to the Tamar, and beyond it in the direction of Dartmoor, renders the problem of their formation one of considerable geological importance. If the formation of these cherts is mainly due to the silica separated from the sea-water by radiolaria, possibly also in part by sponges and diatoms, we must draw a heavy cheque on the bank of geological time to allow for the enormous interval necessary for the accumulation of such a thickness of rock by the gradual deposition of the skeletons of these microscopic organisms. Evidence is however being brought forward from various quarters tending to demonstrate that cherty rocks are of by no means infrequent occurrence in other portions of the geological series, and that, as in the case of our Ordovician and Lower Culm cherts, they originate to a large extent from the remains of radiolaria.

In the Ordovician rocks of Scotland there are important beds of chert filled with radiolaria.*

Of the same age as our Lower Culm cherts, there are extensive deposits of silicious rocks in the Hartz district of Germany mainly composed of radiolaria;

* *Annals & Mag. Nat. Hist.* S. 6, vol. vi. (1890), p. 40.

and in some pieces of this rock the structural details of the tests have been completely preserved, and they are most beautifully figured in the Memoir which Dr. Rüst has prepared.* So far our search for chert with the radiolaria similarly well-preserved has been unsuccessful, but there is no reason why it should not be found in our Radiolarian Culm Series.

Lately a great thickness of chert and jasper rock, filled with radiolaria, in much the same condition of preservation as those in our Culm cherts, has been recognized in portions of the coast ranges of California. The age of the rocks has not been definitely ascertained, but they are probably Jurassic, or earlier.†

The radiolarian deposits of Barbadoes, which are of Tertiary age, have long been known to geologists. As a rule the organisms are preserved in soft, friable shales or marls, from which they can be obtained in great perfection by mere washing; but in some instances the beds have been changed into solid chert, and sections of these under the microscope show that the radiolaria in them have been partially dissolved until they are reduced to the state of mere casts strikingly similar to those in the Culm and other palæozoic cherts. It is evident, from these examples, that in the process of the formation of chert the finer structures and the more delicate forms of the microscopic organisms disappear nearly

* *Palæontographica*, vol. xxxviii. (1892).

† Fairbanks: "Stratigraphy of the California Coast Ranges," *Journal of Geology*, Chicago, vol. iii. (1895) p. 415.

entirely, so that it is but rarely that traces of them are now to be seen in the older cherts.

Other deposits of radiolarian chert have been described; but the instances given above suffice to show that the Cornish radiolarian cherts are by no means exceptional in character, and that we must conclude that they are mainly the product of siliceous organisms.

EXPLANATION OF PLATES.

I am indebted to Miss Gulielma Lister for the annexed sketches of some of the radiolarian forms, with the following notes:

1. Slide 298: Porth, St. Columb. Test spherical, ·18 mm. diameter; seen in hyaline outline on a black ground; eight perforations to quarter circle; on the lower left side the wall seems nearly ·03 mm. thick.

2. Slide 298: Porth, St. Columb. Test spherical, ·14 mm. diameter; perforations closer together than in "1," and more regularly preserved; nine to ten in quarter circle. Wall ·013 mm. thick.

3. Slide 298: Porth, St. Columb. Spherical test, ·21 mm. diameter; about twelve perforations to quarter circle.

4. Slide D 600: Mullion Island. Test oval, showing faint, rather irregular, reticulation; ·125 × ·1 mm. A lower spine is clearly defined, but does not lie at right angles to long axis of test, but rather obliquely; the spine at the right end is indistinct; perhaps they have nothing to do with the original shell.

5. Slide D 600: Mullion Island. Oval test, ·3 × ·25 mm. diameter; wall, ·022 mm. thick; (contains lump of black ——— within); traces of round-meshed reticulation on convex surface; little structure seen in section of wall.

(These tests abound in slide D 600).

6. Slide D 600. Roundish oval test, ·17 × ·145 mm.; wall about ·016 mm. diameter, cracked, the fragments brought together in sketch. There seem to be two short spines attached to the lower side, and two on the upper side; the latter are combined into one by a dark mineral, which gives almost the appearance of a single stout spine. No structure seen, except some striation in wall as viewed in section.

7. Slide D 600. Small black jar-shaped test (?), nearly spherical, ·062 mm. diameter, perhaps not organic. It is hollow, and the surface marked with neat rounded holes, varying from ·003 to ·01 mm. diameter. If it is a shell, one would think something had been broken from the upper end.

8. Slide D. 600. Black sub-spherical test, ·13 mm. diameter; flattened on the upper side, where a stout spine is attached; lattice structure distinct on surface. The shell is broken, and a fragment severed for some distance.

9. Slide D 600. Similar test, near "8" in slide; ·115 mm. diameter; broken, and too opaque to show structure clearly.

10. Slide 207: Mullion Island. Oval test, ·155 × ·125 mm.; half only is left in the section, and this is broken; the halves united in drawing; the roundish holes of lattice structure brightly preserved.

11. Slide 204: Mullion Island. Spherical (?) test, ·175 mm. diameter; fragment only of a hemisphere left; shows brilliant reticulation, with hexagonal holes; there is one large hole, perhaps imperfectly divided by septa, round which is grouped a ring of smaller holes.

12. Slide 204: Mullion Island. A small nearly spherical test, ·07 × ·06 mm. diameter, beset with short spines of varying length; structure not clear, perhaps owing to depth in which the shell is buried in the section.

13. Slide 598 A: Porth, St. Columb. Roundish oval test, ·225 × ·205 mm.; sectional structure distinct, showing hyaline on a greyish ground; wall ·02 mm. thick.

14. Slide B 599: Porth, St. Columb. Spherical test ·205 mm. diameter; shows sectional structure; one large spine distinct, one shadowy; wall, ·03 mm. thick.

15. Slide B 599: Porth, St. Columb. Test nearly spherical, ·17 × ·2 mm. diameter; wall, ·02 mm. thick, with apparently three large spines—two tolerably distinct, one indistinct except the base. Six small blunt spines appear on the margin between two of the large ones; shows sectional and surface structure; wall, ·015 mm. thick.

16. Slide B 599: Porth, St. Columb. Subspherical, ·18 mm. diameter; wall about ·02 mm. thick, with two large imperfect spines, perhaps an apical crest; sectional structure moderately clear; vague appearance of a spine between, but not exactly halfway between, two of the spines; 14, 15, 16 are near one another in the slice; the spines though not very distinctly seen, can hardly be the result of coincidence only, and have no reference to the tests (?).

17. Slide B 599: Porth, St. Columb. Roundish oval test, ·1 × ·09 mm.; wall, ·008 mm. thick; sectional structure well preserved, about twelve perforations to the quarter circumference.

18. Slide B 599: Porth, St. Columb. Probably a large and small test lying together, and not a single double test; there is some appearance of three large spines on the larger sphere, but nothing distinct. As there are about three, at least, of such pairs in this "B" 599 slide, with much the same arrangement, I drew this for the chance of its being good; but from the great abundance of all sizes of spheres here, the pairs are probably only a coincidence.

The sketches were made with the camera lucida, and a magnifying power of 170 diameters.

NOTES BY GEORGE JENNINGS HINDE, PH.D. F.G.S.

Slide 298: Porth, St. Columb. Figs. 1, 2, 3. All these are probably simple spherical forms of *Cenosphæra;* the interiors have been filled with the same dark materials as the matrix of the rock. As a rule, the radiolaria in the section are infilled with clear micro-crystalline quartz; not infrequently the quartz is in radiating fibres.

Simple oval tests, probably of *Cenellipsis,* are likewise common in this slide.

Slide 598 A: Porth, St. Columb. Fig. 13. There appears to me to be a single definite radial spine in this form; a specimen of somewhat more circular outline, but otherwise similar, occurs in the Lower Culm chert of Ashbrittle, West Somerset. It is figured as belonging to *Dorysphæra.* (*Q.J.G.S.* vol. li. pl. xxvi. fig. 5.)

Slide 599 B: Porth, St. Columb. Figs. 14, 15, 16. There is no doubt that the spines belong to the tests from the surface of which they project. It is uncertain whether the tests are spherical or discoidal in form; if the latter, they might be referred to the genus *Theodiscus.*

Fig. 17. A small example, probably of *Cenosphæra.*

Fig. 18. This form consists of a larger and smaller test lying in contact with each other.

Slide 600 D: Mullion Island.

Fig. 5. This and other similar specimens appear to be oval or spherical forms of radiolaria, round and within which opaque ferrous material has been deposited.

Fig. 6. Cannot determine the genus to which this form belongs.

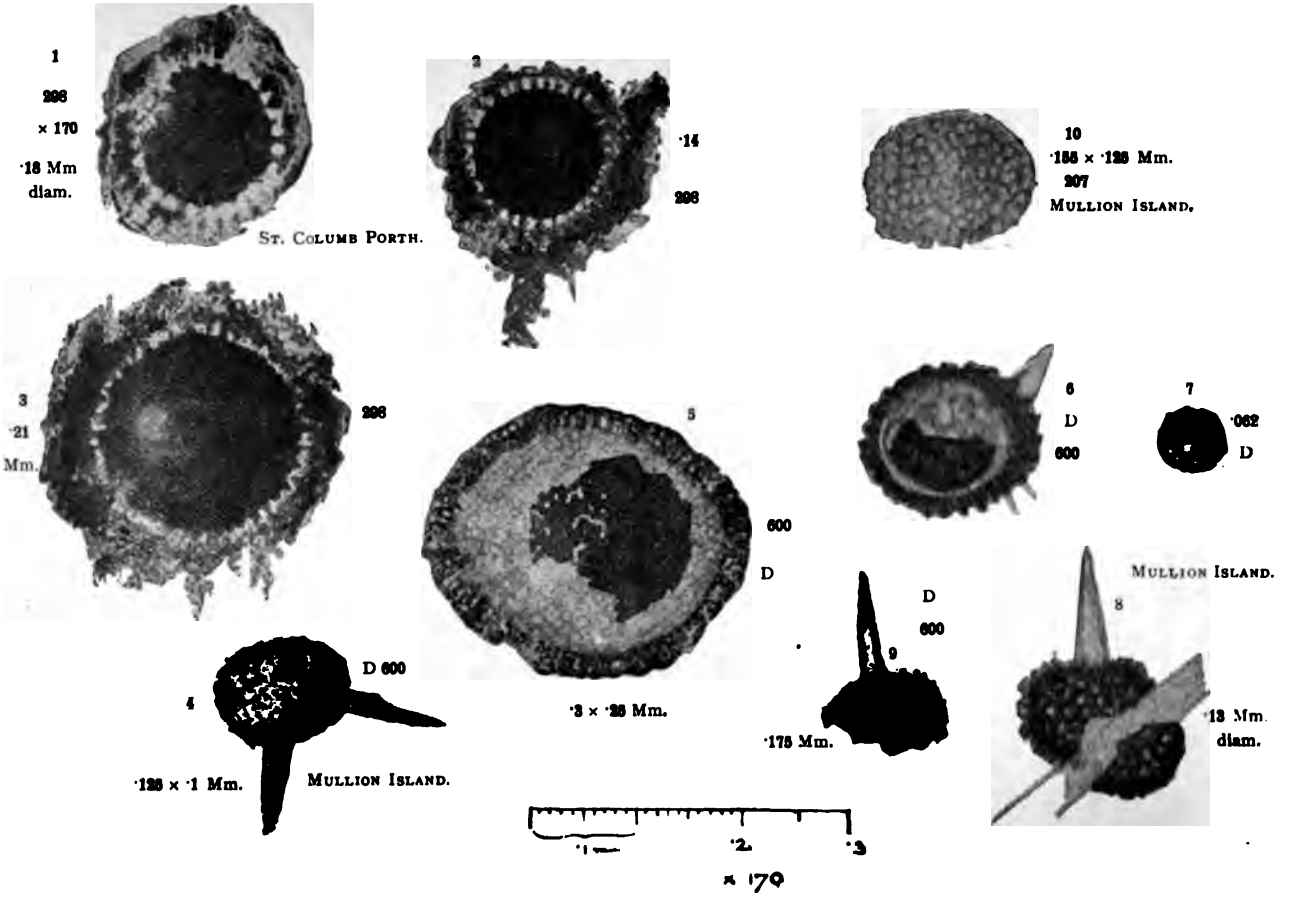
Fig. 7. This minute body is probably inorganic; similar forms occur in the Lower Culm Chert of Carzantic Quarry, near Launceston.

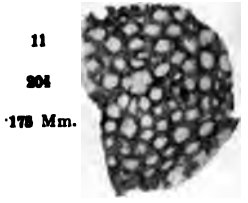
Figs. 8, 9. These may be placed in the genus *Dorysphæra.* In Fig. 8 a quartz vein cuts across the specimen.

Fig. 13. Probably a specimen of *Cenellipsis.*

Fig. 11. Slide 204: Mullion Island. This is probably a fragment of a specimen of *Cenosphæra.*

Fig. 12. Doubtful.

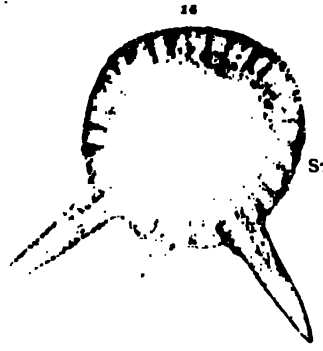

1
296
× 170
·18 Mm
diam.
St. Columb Porth.
2
·14
296
10
·155 × ·126 Mm.
207
Mullion Island.
3
·21
Mm.
296
5
600
D
·3 × ·26 Mm.
6
D
600
7
·062
D
Mullion Island.
4
D 600
·126 × ·1 Mm.
Mullion Island.
D
600
9
·175 Mm.
8
·13 Mm.
diam.
·1
·2
·3
× 179



11

204

·178 Mm.



14

B 599

St. Columb Porth.

·205 Mm. diam.

12

599

B

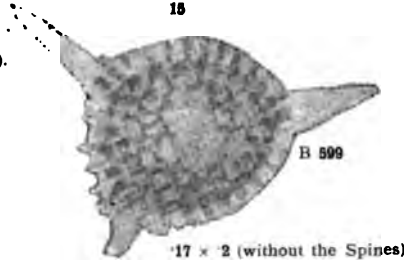
·18 Mm diam.

Mullion Island.

12

204

·07 × ·06 Mm. (without the Spines).



15

B 599

·17 × ·2 (without the Spines).

17

599

B

·1 × ·09 Mm.

test ·006 Mm.

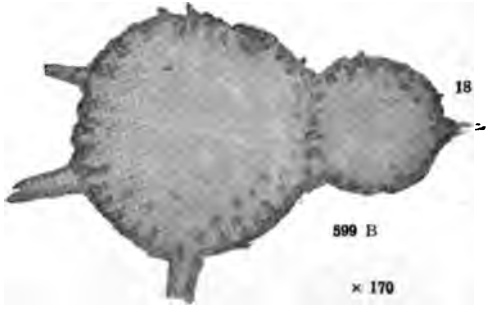
13

A

598

St. Columb Porth.

·225 × ·205.



18

599 B

× 170

SUPPLEMENTARY NOTES ON THE CHERTS AND ASSOCIATED ROCKS

OF ROUNDHOLE POINT, CATACLEWS POINT, AND DINAS HEAD.

By Howard Fox, F.G.S.

(Read 8th November, 1895.)

In the eleventh volume of your *Transactions*, at pages 723, 724, tables of analyses of the above rocks are given.

Since the publication of these tables, Mr. J. J. Beringer has added to my obligations to himself and his pupil, Mr. Arthur F. Hosking, by sending me analyses of specimens of "Greenstone" from the above three headlands.

No. XIV. = Altered dolerite from (G) Roundhole Point. (See diagram, vol. xi. p. 689.)

„ XV. = Altered biotite plagioclase rock from No. 1 quarry, Cataclews Point. (See diagram, vol. xi. p. 695.) This rock is now quarried for road metal.

„ XVI. = Altered dolerite from ("C") Dinas Head. (See diagram, vol. xi. p. 705.)

	XIV. Roundhole Point.	XV. Cataclews Point.	XVI. Dinas Head.
Loss at 100° C	·35	·40	·39
Loss on ignition	7·18	6·38	6·14
SiO_2	42·21	42·81	45·95
TiO_2	1·57	1·90	1·08
Al_2O_3	9·47	14·55	7·23
FeO	23·40	20·52	25·02
P_2O_5	·51	·51	·38
CaO	6·20	3·96	5·17
MgO	2·16	1·62	1·71
K_2O	1·76	2·01	1·51
Na_2O	5·30	5·57	5·91
	100·11	100·23	100·49

Mr. J. Arthur Phillips in his paper on "The so-called 'Greenstones' of Central and Eastern Cornwall," published in the *Quarterly Journal of the Geological Society* in 1878, divides the rocks marked in the Survey Map of the central northern district of Cornwall as "Greenstones" into three distinct classes, namely, crystalline pyroxenic rocks, vesicular lavas, and foliated ash-beds. He finds that the igneous rocks in the neighbourhood of Wadebridge belong to the first of these classes and closely resemble the altered dolerites of Penzance and St. Austell.

The following table of Mr. Phillips' analyses is interesting for comparison with that of the "Greenstones" of Roundhole Point, Cataclews Point, and Dinas Head. It will be seen that the percentage of soda is very similar in all these rocks.

	Altered Dolerite.	"Blue Elvans."		Lava.
	St. Mewan, near St. Austell.*	Slades Br., near Wadebridge.†	Trenewth, near Camelford.‡	Pentire Pt., near St. Minver.§
Water { hygrometric	·30	·40	·30	·51
Water { combined	·67	4·96	·60	3·98
Silica	50·41	46·65	48·23	43·23
Carbonic anhydride		1·90		2·61
Phosphoric „	·83	trace	·37	·97
Alumina	18·91	19·36	19·35	21·37
Ferric oxide	2·44	2·61	3·57	1·69
„ persulphide	·42		trace	·33
Ferrous oxide	11·11	9·55	8·38	9·53
Manganous oxide	·42		trace	trace
Lime	5·90	4·08	8·04	6·66
Magnesia	1·72	5·34	4·14	3·57
Potassa	1·60	·32	1·21	trace
Soda	5·22	4·54	5·84	5·63
Lithia	·11			
	100·06	99·71	100·03	100·08

* *Q. J. G. S.* vol. xxxiv. (1878) p. 472. † *Ibid.* p. 478.
‡ *Ibid.* p. 480. § *Ibid.* p. 482.

NOTES ON CORNISH FOSSILS.

By J. H. Collins, F.G.S.

(Read 8th November, 1895.)

III. THE CRINOIDS.

The fragments of Pelmatozoa hitherto found in Cornwall appear to belong chiefly to the Crinoidea, though there are probably some representatives of the orders Cystidea and Blastoidea.*

Crinoidal remains are recorded from innumerable localities, particularly from the thin limestones and calcareous slates of the south coast, from Port Wrinkle to Porthalla; and of the north coast, from Padstow to Newquay. They have also been met with in considerable abundance in the soft shales and slates of Trelawney, and the grits and sandstones of St. Veep. Some indeterminate fragments have likewise been found inland, to the west and north of Truro.†

* Of the *Camarata*, whose tests are strongly united by suture, it is possible that we have representatives of the families Platycrinidæ, Actinocrinidæ, and Rhodocrinidæ, while the more loosely constructed *Inadunata* are, perhaps, represented by several species of Cyathocrinus.

† "Encrinites in the *débris* of Wheal Hope, Perranzabuloe, were found by Mr. Tweedy in a dark, shining slate, in quantities, some very distinct, some years since." (Peach, 1844.) I regret that I have not as yet been able to confirm this statement by an actual examination of the specimens, nor to find any similar fragments in the locality specified; but I do not in any degree doubt the accuracy of the statement.—J. H. C.

Possibly the Crinnis remains hereafter to be referred to may include some fragments of Palæaster, or of Calycanthocrinus, while some of those from the Ordovician limestones of Porthmellin and Porthalla may be Cystidean. *

Abundant as they are,† the remains are rarely other than portions of columns, which scarcely ever afford the necessary data for specific or even generic determinations. Nevertheless, they have been referred by various writers, with more or less of doubt, to no fewer than seven different genera,‡ specific names being also given in many instances, as stated in my "Working List."§

In arranging the specimens in our Museum, I have made use of the names already given whenever I could be reasonably sure of the identity of the forms referred to. In other cases I have left the fragments unnamed, or assigned merely specific names which are not likely to prove inconvenient hereafter. The assignment of generic names, while the modes of springing of the radials and other essentially generic characters are still unknown, would be clearly unadvisable. The numerous specimens in our museum (at present

* Mr. F. A. Bather says there are no crinoids in the Swedish Ordovicians so far as he has examined them, but that 23 species of Cystideans are known. There are, however, many genera of Crinoids in the Chazy and Trenton limestones, as is well known.

† At Mellendreth one of the limestones is so richly charged with crinoidal fragments that it has been called "Cornish entrochal marble."

‡ Actinocrinus, Adelocrinus, Cyathocrinus, Pentacrinus, Platycrinus, Periechocrinus, and Rhodocrinus.

§ *Trans. R. G. S. C.* vol. IX.

occupying Table Case V.) are mainly casts of fragments of columns or of arms, or isolated ossicles of such. Occasionally the calcareous substance remains, but more frequently this has entirely disappeared, and there remains only a siliceous (or occasionally pyritous) cast of the canals and interspaces or of the exterior of the column. The variations in size and form and in the proportions of the various parts are very considerable. For example:

Columns are cylindrical, elliptical, pentagonal, or pentaphylloidal; simple or branched; and varying in thickness from one-sixteenth of an inch up to an inch or more.

Ossicles are thin, medium, or thick; equal or unequal; simple or compound; their surfaces radiated, grooved, or variously sculptured.

Canals are minute to large; equal or variable in thickness; cylindrical, pentagonal, or pentaphylloidal.

CYATHOCRINUS (?) PINNATUS (Goldfuss) *Actinocrinus* (?) *pinnatus*, &c. The characters, as given by Phillips (*Pal. Foss.* p. 31, and Pl. xvi. fig. 45) are as follows:

"Articulating disc, concave in the central parts, raised towards the edges, and there distinctly radiated; side moniliform; joints alternately larger, canal obscurely pentaphylloidal."

The thickness of the discs is about one-fourth of their diameter, which, in the largest I have seen, is about half an inch. Their surfaces are finely striated radially, the striations being limited to a

ring only, and not extending over the whole surface, (See Plate D, fig. 1, &c.) Specimen No. 194 is a good example from Punch's Cross, Polruan. Compare Nos. 203 (Fowey), 156 to 160 (Pridmouth), 204 (Duporth), and 208 (Crinnis), &c. Compare also fig. 5 from specimen No. 150, which is evidently a related form, but apparently not identical. Compare also the figures of C. (?) variabilis given by Phillips (*Pal. Foss.* p. 31, and Pl. xvi. fig. 48), in which, however, the canal is pentagonal and minute.

A silicified and pyritized specimen from Crinnis (No. 144, Table Case V.) may possibly be related to the foregoing. (See Plate D, fig. 10.) The thinnest part is about one-sixth of an inch, and it widens both towards the base and the calyx. It seems to be composed of moniliform joints, each about one-twelfth of an inch in thickness. The canal is comparatively large, and circular in section. Towards the calyx the joints rapidly become larger and thinner.

CYATHOCRINUS (?) CARINATUS. I have ventured to apply this specific name to forms apparently related to the last, and common in some of the same localities, but which yet are quite distinct in some important particulars, as follows:—

Discs thin (about one-sixth of their diameter), slightly raised in the centre, and having an annular groove on each of the faces, which are finely striated radially, the outer rim being more coarsely sculptured; alternate ossicles slightly enlarged, their

sides distinctly carinated, the canal of moderate size and cylindrical.

The best preserved specimen of this fossil which I have yet seen is a short piece of a stem from the dark, slaty limestone of the Van near St. Austell. This specimen (207), which is entirely calcareous, is represented on an enlarged scale (× 5/1 in fig. 6 of Plate D). In fig. *a* three ossicles are shewn, partly in section and partly in elevation. The distinct "keel" on the edge (suggesting the specific name) and the slight alternate variation in size and thickness, are also well shown in the figure, while *b* shews the cylindrical canal and the varying sculpture of the disc-surface as well as its slight ellipticity.

In this specimen the substance of the joints is now completely crystallized, and exhibits the characteristic cleavage of calcite; but the filling of the interspaces is of a different character, for though it is still carbonate of lime, it is amorphous, and not crystallized.

Fig. 7 in Plate D represents part of a completely silicified stem from Crinnis, which appears to belong to this species. One fragment only shows traces of the body or calyx of the crinoid. This is very obscure, but it seems to show that the basal plates were probably ten in number, and somewhat highly ornamented, as roughly indicated in fig. 7 *b*., Plate D. As yet I have seen no complete stem; the longest fragment in our collection is between four and five inches in length, and in this no tapering is visible.

CYATHOCRINUS (?) or ACTINOCRINUS (?) TENUISTRIATUS (*Pal. Foss.* p. 31 and Pl. 16, fig. 44). "The joints exceedingly thin, with very fine radiations; canal minute; edge muricated or plain." It is possible that specimen No. 206, which is sketched in fig. 8, *a*, *b*, *c*, of Plate D, may be identical with the specimens described and illustrated by Phillips.

CYATHOCRINUS (?) LEPTOS. Here, again, I have ventured to give a specific name suggested by a very important character. The discs are very thin, often not more than one-fiftieth of an inch (Plate D, fig. 9*a*)—hence the specific term leptos. The canal is small and cylindrical. A few of the plates are circular, but in general they are distinctly elliptical. This fossil is found in considerable abundance at Crinnis, but nearly always as isolated discs. The outer rim of the ossicle is grooved rather than striated radially, as shewn at *b*. A smaller but apparently related form is seen in specimen No. 198 from Polruan (Pl. D, fig. 11). The ossicles are less than one-fiftieth of an inch in thickness, and their articulating surfaces are very finely but distinctly striated radically. The canal is small and obscurely pentaphylloidal. (Compare with Billing's sketch of Rhodocrinus gigas, Decade iv. Canadian Geological Survey, Plate vi. fig. 3.)*

CYATHOCRINUS PLANUS, reported from Crinnis

* "The most common crinoid stem in the Girvan district is large, plain, circular, composed of equal, regular, close-fitting, unornamented ossiolea, with the articulated surfaces a little bi-concave, and finely striated radially."—*Fossils of Gervan*, p. 328, and Plate xxii. fig. 5.

(Peach, 1844), I have not yet identified. It may be C. carinatus or C. leptos.

CYATHOCRINUS (?) NODULOSUS (or nodosus). A fragment so named is figured by Phillips (*Pal. Foss.* Pl. xxii. fig. 46) "from Torquay"; and Peach mentions "a beautifully nodulated column" from the Chough Rocks. (*Trans. R. G. S. C.*, vi.) The fossil at first referred to Pentacrinus by Peach (from East Looe, ascending Guns Hill) perhaps belongs here. He describes it as follows:

"On this spot . . . the finest encrinite I ever saw, part of column tubercled, four auxiliary side-arms, three on one side, and one on the other; the pelvis peculiarly marked, something like a quartered shield; several of the tentaculæ beautifully pinnated; the extreme ends of one of the tentacle heads turned something like the recent P. Caput medusæ of the Bridgewater treatise." (*Trans.* vi. 12.) This specimen should be in the museum, but I have not yet succeeded in identifying it. The impression and portions of stems [specimens 130 (Bodmin) and 142 (Crinnis), Plate D, figs. 12 and 13] appear to be near to, but not identical with, Phillips's specimen. In the general form of the stem there are distinct resemblances to Glyptocrinus. Compare also specimen 200, from Polruan, which exhibits traces of a large obscurely pentaphylloidal canal, and of calcareous substance.

CYATHOCRINUS (?), figs. 14 and 15, Plate D. These are sketched from casts of what appear to be large annulated crinoid columns. As there are no traces of

structure, it is not possible to say whether they are properly placed with the other specimens described, under the name Cyathocrinus, or not. Such, or very similar, casts have been found at Polgover Cross (specimen 141, Table Case V.), Polruan, and Trelawney. Some of them may possibly be casts of Orthoceras; but I think not, for they are usually associated with undoubted crinoidal fragments. Figs. 1 and 2, Plate E, are also sketched from such column impressions at Trelawney.

Associated at Trelawney with casts of fragments of large columns, somewhat like figs. 14 and 15, Plate D, are certain impressions of ossicle surfaces and interspaces represented in figs. 16, 19, and 20. Fig. 19 is sketched (slightly magnified) from specimen 479, which represents a cavity formerly filled with the calcareous substance of an ossicle perfect on its lower surface. The canal was evidently minute, and the deeply excavated ossicle was very finely striated radially over its whole surface. Fig. 16 is an almost identical form from the same locality.

Fig. 17, Plate D, is sketched from a fragment (spec. 154, Blackhead) at least four inches long, showing a series of bead-like crinoid joints, each of which is a little displaced laterally. The radiated joint surface and small canal are shown also.

Fig. 18 is sketched from a somewhat similar specimen (No. 193) from Polruan. Here the ossicles (*b*) are still calcareous, while the interspaces (*a*) are silicified.

Fig. 20 is sketched from a fragment of the same

stone as specimen 479, × 8/1. Here there is a distinct conical depression in the centre, indicating a corresponding elevation on the surface of the ossicle. The surface is marked with sixteen distinct radial groovings, as indicated in the sketch.

CYATHOCRINUS? ANNULATUS (Encrinites annulatus, *Couch*).—This may be the same as C. glomeratus = E. glomeratus? Associated with the column sketched in figs. 1 and 2, Plate E, are certain partly-separated discs, sketched in fig. 3. (Spec. 138, &c.) From some indications, I am inclined to think that these ossicles or discs now displaced were not alike in form above and below, but were dished somewhat, like fig. 4. A different but analogous form, sketched from specimen No. 205 (from near Yeolmbridge, × 4/1), is illustrated in fig. 14. It may perhaps be a cast of the chamber walls of an Orthoceras, though it has some resemblance to fig. 4, Plate E, which is clearly crinoidal.

RHODOCRINUS.—Casts of ossicles, which have been referred to this genus by Peach and others, are abundant in the sandstones of Highgate Quarry, St. Veep. They occur also at East Looe, West Looe, and St. Catherine's Point, Fowey. The ossicles are pentaphylloidal in form, the edges rounded, and the joint surfaces deeply indented by star-shaped pentagonal depressions, as shown in figs. 5 and 6, Plate E, which are drawn a little larger than natural size from a St. Veep specimen, canal minute, cylindrical, or pentaphylloidal.

INCERTÆ SEDIS.—Fig. 7 is sketched from specimen

No. 155, × 4/1, which was found at Appletree Cliff, between Charlestown and Par; *a* is the cast of the pentaphylloidal canal, with traces of the calcareous ossicular substance still remaining; while *b* shows the cross-section of the canal. Nos. 127 and 128 from near the Blackhead, are very similar. Specimens 126, from Padstow (fig. 8, × 4/1), and 136 from Crinnis (fig. 9, × 4/1), should also be compared.

Fig. 10 × 3/1, sketched from specimen 196, represents a cast of a portion of a crinoid stem, with thick cylindrical canal and silicified inter-ossicles.

Fig. 11, from specimen 129, is a curious twisted form (× 2/1) from Crinnis, the pentaphylloidal section of the canal is shown at *b*.

Fig. 12 is sketched a little more than natural size from specimen No. 131 (Bodmin), and is still more twisted. Is this the "rope-like" encrinite of Peach? It is three inches long, and the cavity is about $\frac{1}{8}''$ diameter, and lined with calcite, as indicated at *aa*.

Fig. 13, sketched from specimen 222, from Crownall Bay, and a little magnified, is a curious silicified stem, The decangular section of the ossicles is shown at *b*.

Figs. 15 and 16 are sketched from a specimen (480 *b*) found at the Van cliff, near the Blackhead. This is a very remarkable form, but I am disposed to think it a crinoid. The black lenticular discs occur in groups of four, the forms of which are illustrated (× 4/1) in elevation in fig. 15, and in

section in fig. 16. They seem to be casts of the interspaces between calcareous ossicles having the peculiar form indicated at *aa* in fig. 16. There is no indication of a canal joining the discs. Both ossicles and discs are separated from the general mass of rock-substance by the dark border marked *bb* in fig. 16, the thickness of which varies, as indicated in the sketch.

An almost identical form (specimen 481, marked by C. W. Peach as coming from Fowey) has the discs elliptical instead of circular, and grouped in threes instead of in fours.

DESCRIPTION OF PLATE D.

Fig. 1. *Cyathocrinus* (?) *pinnatus*. Phill.

a. Part of stem from a medium-sized specimen (No. 194), natural size.

b. Section of three ossicles, × 2/1.

Fig. 2. Natural mould showing form of a single ossicle, × 3/1 (specimen 160).

Fig. 3. Surface of disc showing ring of radial striations, × 2/1.

Fig. 4. Cast of ossicle surface of an allied form, × 4/1 (specimen 194).

Fig. 5. Cast of ossicle surface of a similar form, and of the canal, × 4/1 (specimen 150).

Fig. 6. *Cyathocrinus* (?) *carinatus*.

a. Shewing edges and sections of three discs, with their articulations, × 5/1.

b. Surface of disc shewing striated and radially-grooved surface (207), × 5/1.

Fig. 7. Ditto (?). A common silicified form at Crinnis (specimen 132, &c.)

a. Fragment of silicified stem, natural size.

b. Traces of under surface of calyx, do.

Fig. 8. *Cyathocrinus* (?) or *Actinocrinus* (?). From specimen 206 × 3/1.

a. Section of three ossicles, shewing alternations of size and form of the interspaces.

b. Shewing form of canal and character of surface striations.

c. Shewing external form of column.

Fig. 9. *Cyathocrinus* (?) *leptos.*

a. Shewing sections of three ossicles or discs, natural size.

b. Surface of disc, shewing small central canal and waved rim (specimens 420–423).

Fig. 10. *Cyathocrinus* (?) Specimen 144.

a. Curved stem pyritized, enlarging towards the head, slightly magnified.

b. The same in section.

Fig. 11. Portion of stem composed of very thin finely-radiated plates, × 3/1 (specimen 198).

Fig. 12. Portion of stem resembling *C. nodulosus*, × 2/1 (specimen 130).

Fig. 13. Portion of stem, × 2/1 (specimen 142).

Fig. 14. Cast of stem, specimen 200 (slightly magnified).

Fig. 15. Cast of stem (?), specimen 141 (natural size).

Fig. 16. Cast indicating form of ossicle, and portion of canal, from Trelawny, slightly magnified.

a. Shewing curve of interspace.

b. Shewing striations of the surface, &c.

Fig. 17. Specimen 154, slightly magnified.

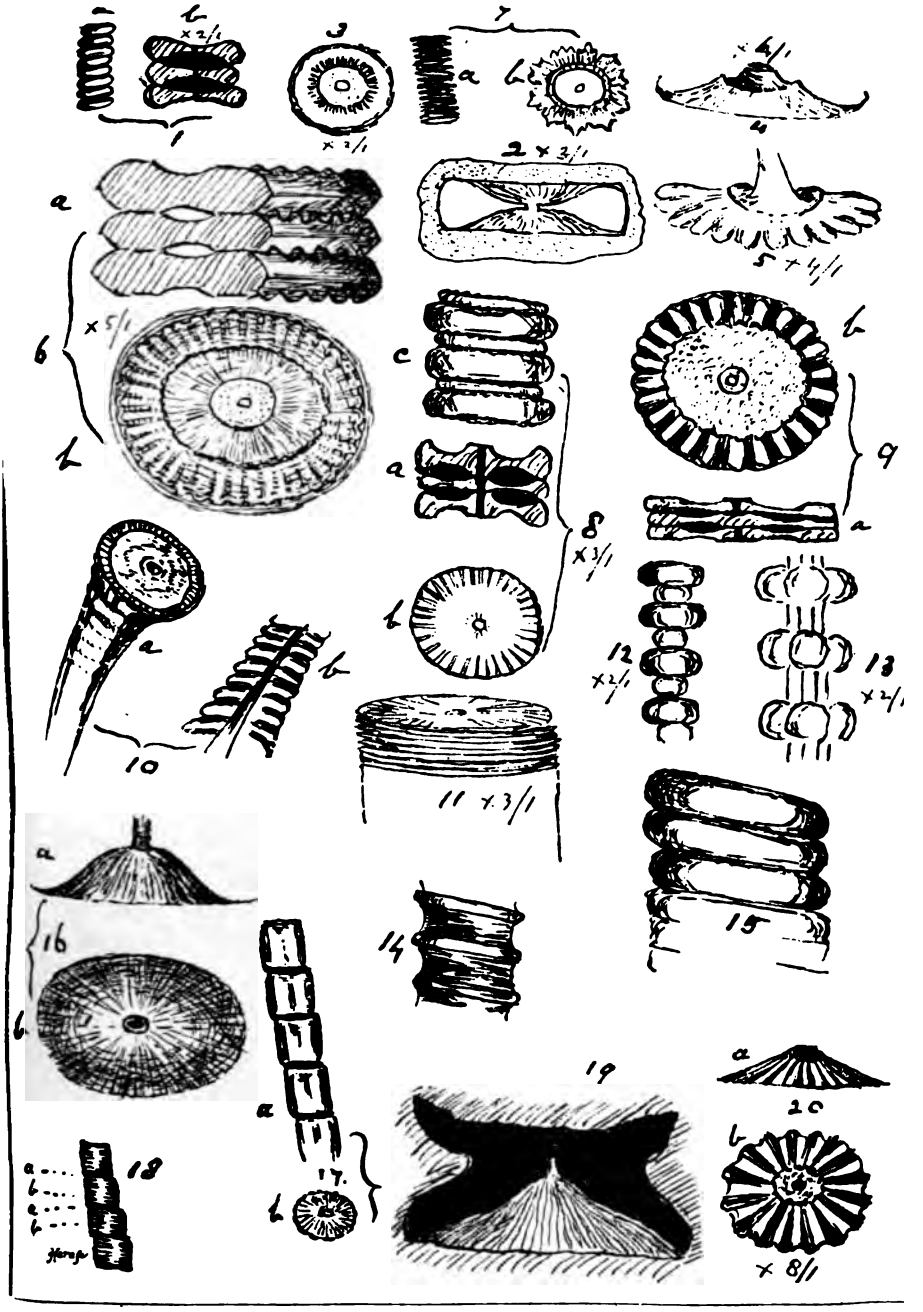
a. Shewing displaced ossicles.

b. Radiated surface of ossicles.

Fig. 18. Specimen 193, shewing displaced ossicles, natural size.

a. Silicified interspaces.

b. Calcareous ossicles.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b
× 2/1
1
3
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7
a
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4
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c
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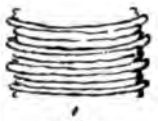
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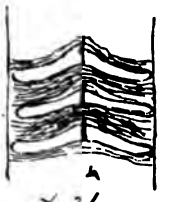
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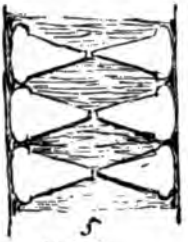
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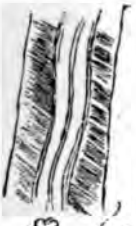
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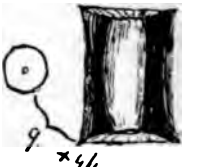
×2/1

15 ×4/1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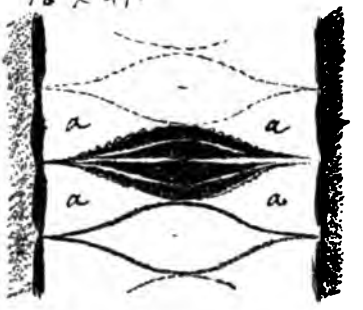
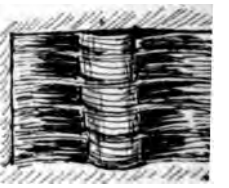
16 ×4/1

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14 ×4/1

11
13
b

Fig. 19. Cast and cavity resembling Fig. 16. From specimen No. 479, slightly magnified.

Fig. 20. Cast of interspace of minute ossicle from specimen No. 478, × 8/1.

DESCRIPTION OF PLATE E.

Fig. 1. Cast of crinoid column from specimen 138, × 2/1.

Fig. 2. Ditto, from specimen 139, × 2/1.

Fig. 3. Partly separated ossicles of *Cyathocrinus* (?) ***annulatus***, from specimen 138, natural size.

Fig. 4. The same in section and before displacement × 2/1.

Fig. 5. *Rhodocrinus* (?) from St. Veep. Three ossicles in juxtaposition, × 2/1.

Fig. 6. Ditto, surface of an ossicle, showing star-shaped depression.

Fig. 7. Cast of canal, &c. (specimen 155), from Appletree Cliff, × 4/1. At *b* a section of the canal is given.

Fig. 8. Cast of canal, &c., from Padstow, × 4/1 (specimen 126).

Fig. 9. Cast of canal from Crinnis, × 4/1 (specimen 136); *b* shows the circular section.

Fig. 10. Cast of cylindrical canal, with interspaces (specimen 196) × 3/1, from Polruan.

Fig. 11. Cast of twisted canal, &c. (specimen 129 × 2/1), from Crinnis.

Fig. 12. Cast of twisted canal (?) (specimen 131 × 2/1), from Bodmin.

Fig. 13. Decangular stem (specimen 222, natural size), from Crownall Bay.

a. elevation, *b*. cross-section.

Fig. 14. Curious form from near Yealmbridge (specimen 205 × 4/1).

Fig. 15. Elevation of specimen 480b × 4/1.

Fig. 16. Section of specimen 480b × 4/1.

a = the ossicle. *b* = the stem-wall.

I may remark that these crinoids, like most of the other fossils found in Cornwall, though similar to those found in other districts, are rarely identical. In fact, Cornish fossils differ from other fossils at least as much as Cornishmen do from other men. I do not doubt that many absolutely new species will ultimately be founded on the Cornish examples, though it must be a slow process, as the organisms are usually so fragmentary and so much damaged. And with this end in view I would venture to repeat my appeals to field workers to make this museum the final resting-place of all their "finds" while they are fresh and undamaged, and while their recollections are clear as to their exact localities.

SOME GEOLOGICAL NOTES FOR 1895.

By Francis J. Stephens.

(Read 8th November, 1895.)

Two interesting discoveries have been made this year (1895), both bearing on the radiolarian chert beds of South Cornwall.

At Whitsuntide, certain obscure organisms were found in the Porthallow district, in shales interbanded with cherts.

These were decided by Professor Lapworth to be graptolites, and he has identified and figured no less than seven different species, these, too, ranging from Arenig forms (Lower Ordovician) to Llandovery, or Lower Silurian.

Some progress has been made towards the working out of these fossiliferous shales, and it is to be hoped that further notes may be forthcoming upon this discovery by next year. It is necessarily, however, a work of much time and patience. These graptolites, with Professor Lapworth's figures, lie upon the table.

In the St. David's district of Pembrokeshire certain cherty rocks were found last August, in Lower Palæozoic rocks there. The Arenig, Llanvirn, and Llandeilo rocks, all rich in graptolites and other fossils, were found to contain bands of hard cherty

rocks, which are not unlike the radiolarian cherts of Porthallow, and elsewhere in Cornwall.

The four sections cut so far are rather disappointing, although in one, presumably of Llandeilo age, faint indications of sponge spicules are seen. It will be interesting if further investigation shows radiolarian structure in these cherts also, situated as they are in a richly fossiliferous Lower Palæozoic district.

Sections and specimens of these cherts are also upon the table. They were examined by Dr. Hinde, F.G.S., of Croydon.

Royal Geological Society of Cornwall.

THE EIGHTY-THIRD

ANNUAL REPORT

ETC., ETC.

PENZANCE
1897.

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Thomas Clark, Michell Hill Terrace, Truro.

The Rt. Hon. Leonard Courtney, M.P., 15, Cheyne Walk, Chelsea, S.W.

J. R. Daniell, Polstrong, Camborne.

G. Davey, Fernleigh, Redruth.

Thomas Algernon Dorrien-Smith, Tresco Abbey, Isles of Scilly.

Mrs. Downing, Trereife, Penzance.

Francis Gilbert Enys, Enys, Penryn.

John Davies Enys, Enys, Penryn.

The Viscount Falmouth, Tregothnan, Falmouth.

Thomas Willis Field, Chymorvah, Marazion.

Howard Fox, F.G.S., Falmouth.

Miss Fox, Penjerrick, Falmouth.
Carew Davies Gilbert, Trelissick, Truro.
Francis Harvey, Glanmôr, Hayle.
Christopher H. T. Hawkins, Trewithen, Probus.
Rev. Prebendary Hedgeland, M.A., Penzance.
Frederick Holman, Penzance.
Mrs. Husband, 42, Godwin Road, Cliftonville, Margate, Kent.
Thomas King, M.A., Falmouth.
J. B. Jennings, Johannesburg, South Africa.
Charles Day Nicholls Le Grice, Penzance.
David Howell, Rosehill, Penzance.
Fortescue William Millett, Marazion.
John Penn Milton, Penzance.
Hugh Montgomerie, M.D., Penzance.
The Earl of Mount Edgcumbe, Mount Edgcumbe, Devonport.
Henry Palmer, Manor House, Medomsley, R.S.O.
Walter Pike, Camborne.
Thomas Roxburgh Polwhele, M.A., F.G.S., Polwhele, Truro.
Robert Hawker Peniel Preston, Penzance.
The Lord Robartes, Lanhydrock.
Major Ross, Penzance.
Charles Campbell Ross, Carne, Penzance.
Rev. St. Aubyn Molesworth St. Aubyn, Clowance, Camborne.
The Lord St. Levan, St. Michael's Mount.
William Bickford Smith, Trevarno, Helston.
George John Smith, Treliske, Truro.
Francis J. Stephens, Ashfield, Falmouth.
John Symons, M.R.C.S., Penzance.
Rev. John Tonkin, Treverven, Buryan, near Penzance.
Colonel Arthur Tremayne, Carclew, Penryn.
Sir Walter Trevelyan, Bart., Nettlecombe Court, Taunton.
The Bishop of Truro, Trenython, Par Station.
Arthur Pendarves Vivian, F.G.S., 26, James Street, Buckingham Gate, London, W., and Glan Afon, Taibach, South Wales.
Nicholas J. West, The Turret, West Heath Road, Hampstead, London, N.W.
John Westlake, Q.C., River House, 3, Chelsea Embankment, London, S.W.

ASSOCIATES.

J. T. Blight, F.S.A., Penzance.
J. H. Collins, F.G.S., 14 and 15, Broad Street Avenue, London, E.C., and Wroxall House, 162, Barry Road, London, S.E.
John Sweet Doidge, Penzance.
William Eddy, Boscaswell, St. Just.
William Gregor, Swansea.
William Hollow (formerly Manager of the Providence Mines), Leyton, Essex.
R. T. Hall (formerly of the Cape Copper Mines), Africa.
Benedict Kitto, F.G.S., 26, Lancaster Road, Finsbury Park, London, N.
S. Mitchell, Swansea.
Francis Oats, F.G.S., St. Just.
John Phillips, Australia.
T. B. Provis, A.Inst.C.E., Finsbury Chambers, 76, Finsbury Pavement, London, E.C.
John Rowe, The Terrace, St. Just.
Stephen Thomas.

The Secretary requests the favour of his being informed of any inaccuracies in the foregoing lists.

THE

ANNIVERSARY ADDRESS OF THE PRESIDENT,

T. R. POLWHELE, ESQ., M.A., F.G.S.,

To the General Meeting, 10th Nov., 1896.

LADIES AND GENTLEMEN,—In this my second and last year of office as your President, it is with deep regret I have to announce the loss of your late Secretary, Mr. George Millett. You all know what a valuable officer he was, but perhaps only one, intimately associated with him can see, how by his methodical habits he has brought the business of the Society into such systematical form, that the work of his successor will be reduced to a minimum. That he appreciated the value of this Museum is shown by his having left his collection of fossils to be placed in it. Your Library and Museum are in good order. All the specimens in the latter are properly placed and well labelled, the keys are all numbered and placed in a cupboard, which is kept locked, and no one can have access to them unless he knows where the key of the cupboard is deposited. The documents of the Society are also arranged, consequently the duties of the new Secretary and Curator will be light, and we need not have one with a very scientific education. But we must not forget that we have a very valuable property in this building, and our Curator should be someone we can thoroughly trust, one who will constantly look round and see that none of the specimens are missing.

As you know, Mr. G. Millett held the joint office of Secretary and Curator, and I am afraid we cannot separate the two offices, as there is no salary for the Secretary. Mr. John Carne, who provided the salary of £50 a year, expressly stated in his will

that it was for a Curator; whoever therefore you appoint to this office, must also undertake the duties of the Secretary.

When the vacancy took place your Council had a meeting, and out of several candidates selected Mr. John Cornish to fill the two offices *pro tem.*, so as to carry on the work of the Society, and it is for you to-day to say if you will confirm that appointment.

I should very much like to see this Institution made more useful. Had the Mining School been here, or this building at Camborne, an amalgamation might have been effected, to the advantage of both, but I am afraid they are too far apart for that to be possible.

But that an affiliation in some way might be brought about is more likely, by the pupils paying say 10/- a year, or £1 for the two years they are at Camborne, towards getting down a good Geological lecturer to give a course of lectures, with the specimens here to demonstrate them, on subjects in Geology, which would be of use to them. For instance the filling up of the fissures in the earth's crust with carbonate of lime by the water process, or other fissures with metalliferous crystals by the electric process. To these lectures one or two field surveys might be added. Failing affiliation we might try something like the University course of lectures. If we could get say 20 or 30 from the Camborne School, and about 20 more from outside, one of the Surveyors of the Geological Survey might be induced to take part of his holidays down here, and give us a fortnight's course, say two lectures and a field survey each week. I am in communication with Mr. Beringer, of Camborne, and hope something may come of it.

By Mr. William Bolitho's will, as you are aware, the Bolitho Medal "is to be awarded each year to such member of the Royal Cornwall Geological Society, whether ordinary, honorary, or associate, whose attainments, labours, and discoveries, in Geological or Mineralogical science, shall in the opinion of the President and Council of the said Society best deserve recognition."

The Council, I am very pleased to announce, have this year

awarded the medal to an old friend of mine, Mr. Robert Etheridge, a man who has given his whole life to these two sciences. We were associated for several years on the Geological Survey of the United Kingdom, and I have received valuable assistance from him in determining the species of various fossils in the strata of this country. I can well remember the time when I was rather angry with my friend, for he was the cause of my having to resurvey a portion of my work. This came about in the following manner. I was sent to carry on the work of another Surveyor, part of which was to trace the boundary between the great and inferior Oolite. Now a certain bed of rock between these two was represented as belonging to the inferior Oolite by my predecessor, and as having died out, but I found a detached portion, which we call an outlier, further on. It contained the characteristic fossils of the inferior Oolite, and was placed with the inferior Oolite by my predecessor, and sad to say my friend, when fossils were sent to him, confirmed this opinion. Later on the Palæontologists changed their minds, and removed this bed to the greater Oolite, and the work had to be done over again.

However, I will forgive my friend for this, and heartily congratulate him on the award of this medal to which he is eminently entitled; and in order that a record may be kept in our transactions as a justification for this award, I must now give you an account of what my friend has done for science.

Mr. Etheridge commenced his public career as Curator to the Museum of the Philosophical Society in Bristol (from 1850 to 1857). Here he was also lecturer in Botany in the British Medical Schools, and in Geology and Palæontology in the British Philosophical Institution.

Fortunately for the Geological Survey of Great Britain, Mr. Etheridge now came under the notice of Sir Roderick Murchison, the Director-General, and he appointed him to the post of Palæontologist to the Survey and Curator of the Museum of Practical Geology in Jermyn Street, July, 1857.

During the twenty-four years he was attached to the Survey, Mr. Etheridge prepared numerous Palæontological reports,

appendices, and lists of fossils, to accompany nineteen separate memoirs of the Geological Field-Surveyors upon various parts of England and Wales; also a report on the Palæontology of Jamaica. For fifteen years he gave forty demonstrations annually, in Palæontology, to the students of the Royal School of Mines, at that time attached to the Museum of Practical Geology, Jermyn Street. Mr. Etheridge rearranged the entire Palæontological collection at Jermyn Street, and prepared a catalogue of every specimen in the collection. This catalogue was printed by the department, with a preface by Professor Huxley. And last, but not least, he reduced our own Palæontological collection from chaos to what it is now, a help to all Geological students.

In 1881 Mr. Etheridge transferred his services, with the sanction of the Treasury, from the Geological Survey and Museum to the Natural History Museum, where for ten years he occupied the post of assistant keeper in the department of Geology. Here he devoted himself specially to the arrangement of the extensive collection of Moortibrata, naming and classifying the very large groups which occupy galleries vii., viii., x., and xi. The whole of the British Mollusca and the British Bractiopoda in gallery viii. have also been mounted, named, and arranged by him. His last and most important work has been the preparation of a Stratigraphical collection for gallery xi., to illustrate all the British sedimentary rocks of Great Britain.

Mr. Etheridge's publications have been numerous. Besides his twenty-five larger works, he has contributed to nineteen memoirs of the Geological Survey.

He is the author of a report on Thames mud and Thames water, being based upon a microscopic examination of eighteen samples of mud and deposit, and two or more samples of water taken from the river Thames, giving a detailed account of each sample, both for living organisms, the organic matter in a state of decomposition, and the inorganic mineral residuum, issued as an appendix to report relating to the main drainage of the Metropolis, ordered by the House of Commons, and printed in 1857.

Mr. Etheridge was also engaged to prepare maps and section, and to give evidence before the Royal Commission, in relations to the Somersetshire coal fields, and especially in reference to the probability of finding coal under the Permian red sand-stone and other superincumbent strata.—*Report of the Royal Commission on Coal, 1871.* As an officer of the Museum his courtesy and readiness to impart scientific information to students is well known.

Now to continue the subject of my last address. You may remember I pointed out to you last year, how in consequence of the advance of the science of Astronomy, the improvements in Astronomical instruments, etc., Astronomers are now able to study worlds not only completed, but also in process of formation and decay.

They can therefore give us a fair idea of how our own world was commenced, by the collection of aerolites by the vapours condensing on them as they revolved in space, keeping the whole earth in a steamy mist, so that neither sun, moon, nor stars could be seen from it. Then as the earth began to cool a crust would form on its surface, this would be broken up and incorporated with a new crust, just in the same manner as you may see river or pond ice broken, and reformed into hummocks.

Now imagine this to have gone on for ages and ages, till at last small hills and valleys would be formed, the vapours condensing on the hills and running down the valleys would form rivers, those running into the smaller depressions would form lakes, and again further on into larger depressions would form oceans. But as the earth became still cooler, this steamy mist, which hid the earth from other worlds, would become rain, for the supply of rivers and oceans, and the sun, moon, and stars would appear as in the graphic words of the Bible,—"The earth was without form, and void; and darkness was upon the face of the deep. And the spirit of God moved on the face of the water. And God said, let there be light: and there was light. And God saw the light, that it was good: and God divided the light from the darkness," etc.

We have now got the earth a steaming hot mass, revolving in space round the sun, which is drawing it towards itself. The moon on the other hand revolves round it, and has also an attraction for it, hence when they are both on the same side of the earth we get high tides. The earth has so far cooled down that the steamy mist has turned to rain, and the sun, moon, and stars have become visible. But it is not yet fit for life, its surface is broken and reformed again and again, till it is so far cooled down that the crust becomes hardened enough to resist the molten matter from breaking through. Now commences the period of degradation and denudation; the sea thunders on the cliffs grinding them down to sand, the rivers wash down the debris from the hills,—these together form plains, poor and without any nourishment. A few lower forms of mosses may find an existence; but till these decay and form some kind of food, nothing can exist. But while this formation of food is going on the earth is still going through violent convulsions, its crust is broken and reformed again and again.

Vegetation now appears on the surface, followed by insects and worms to feed on it; later on they are followed by birds and fishes who feed on them. Next come the inferior animals, larger animals follow these. Last of all comes man, to have dominion over them all.

As the earth get still cooler and more solid there are other forces that come into play to change the form of its crust. Let us therefore now consider one of them, namely gravitation. As the earth revolves round its axis, the parts about the equator, having further to travel than those about the poles, naturally have a tendency to fly away from the centre of the earth, while those about the poles, having a less distance to travel, remain practically in the same place (in the same manner as the mud on a revolving carriage wheel flies off at the tires, but remains on the axle boxes). But as the equatorial parts of the earth swell out from the centre of the earth, those about the poles have a tendency to be drawn in towards the centre to fill the vacuum, and the earth becomes, as the Geography

books say, "a round body like an orange, flattened at the poles." Hence the crust of the earth in the equatorial regions is not so dense as that at the Polar regions, and more liable to be fractured. In other words the fractures in the earth's crust are more liable to follow the parallels of longitude than latitude. That this is the case is proved by the fact that the chief upheavals have a general tend from north to south. Take for instance that most obvious one, the mountains which run from the north of North America to the south of South America.

These north and south mountains are formed of igneous matter, thrown up through these fractures from the centre of the earth, and carrying all the later strata on their backs, causing the dip in these strata. The Himalayan chain of mountains on the other hand run from east to west, but they are more recent and are not igneous.

There are other forces which have taken part in the formation of the earth's crust, but we have not time to examine them all to-day. There is one, however, which I must mention, as it is rather important, namely the Magnetic. When one portion of the earth becomes more dense than another, this force, like electricity, rushes from the negative to the positive pole, but as these poles are not constant, we know the earth is sometimes more dense in one place, and sometimes in another. If we take the mariners' compass we find it does not point to the North Pole in this part of the globe, but there is a table which shows the mariner what the variation is in different parts of the globe. I have here two maps which show where the Magnetic poles are at the present time. That is not the purpose for which I brought them here, but rather to show as true a map of the globe, on a flat surface, as we can possibly get. If you compare the ordinary map of the globe in a common atlas on Mercator's projection with the globe itself, you will find it is anything but correct, the polar regions being greatly enlarged. This projection is strictly geometrical, has the great advantage of giving a good perspective representation of the surface, and it represents the different parts of the globe with little distortion. It is supposed to be taken from the

centre of the earth, the globe being transparent, in the same manner as the map of the stars is taken from the earth as centre, the atmosphere being transparent. Having now considered some of the forces which act in the formation of the physical Geology of the earth,—now as we cannot very well build up the physical Geology of the earth from the beginning, let us see what we can do by going backwards from the known to the unknown. For this purpose we will take the very upheaval I have already mentioned, and see what have been and may be the results in consequence of it.

This upheaval of a mountain chain from near the North Pole to nearly the South Pole has caused a vast lake to form, called the Atlantic Ocean, which has no outlet from the North Pole to Cape Horn on one side, and the North Pole and Cape of Good Hope on the other. The earth moves from west to east; the land being fixed follows it in the same direction, but water being moveable has a tendency to hold back and travel in the opposite direction, being drawn by the attraction of sun from east to west. For the same reason the water from the north Polar region and also from the Indian Ocean round the Cape of Good Hope is drawn into this lake, also causing swift currents in the lake, as well as bring solid matter from the north in the water, and blocks of stone on the backs of glaciers. Then we have almost all the large rivers in the world depositing their burdens in this lake. From Africa we have the Nile, the Niger, the Congo, and in fact all the rivers except the Zambesi and a few small ones on the east coast. From Europe we have all but the Volga and a few small ones that lose themselves in the Caspian Sea. From North America we have virtually all, the Columbia being the only large river emptying itself on the other side. From South America we may say all, for in the map of the world I find none even named as falling into the Pacific.

All these rivers are pouring into this lake the debris of mountains, hills, and plains, mud, gravel, sand, stones, trees, etc.; even a few Atlantic liners as fossils for future Geologists. The water of this lake is evaporated, and goes back in the

form of rain to bring down further solid matter. Year after year this work is repeated, but none of the solid matter is ever returned. On the other hand take the Pacific, few rivers empty themselves into it, very little debris is carried into it; true there are a few coral islands formed in it, but they are built up with the material taken from the spot.

What must and can be the only result of this vast accumulation of matter in one half of the globe, and comparatively none in the other? The density of these parts of the globe will be changed, and the axis of the earth will take a new direction, just in the same manner as the mast of a boat takes a new direction when the ballast is moved from one side to the other. In other words the poles will evagate, which as I pointed out to you in my last address Astronomers now allow has taken place before this, or else we shall have one of those great debâcles, which many Geologists believe have taken place at vast intervals on the face of the earth. We will now consider how this may take place on this part of the globe. The current which comes up the S.W. coast of Africa, and is drawn westwards by the sun till it beats on the east coast of the Caribbean Sea and the Gulf of Mexico, not being able to pass westwards is shunted back (after being warmed in these hot seas) northeast, up to the North Pole, warming our shores in winter on its passage north. Now suppose this current which is working away at the east coast of the isthmus of Panama should at last break through this isthmus, or should the Atlantic be filled up to such an extent as that the water should rise and flow over the isthmus and cause a breach between North and South America, it would so change the course of this currrent that the effect would be felt on all the coast of Europe, Africa, and America, and change the climate of all of this part of the globe.

What therefore is now taking place we may reasonably conclude has taken place more than once in the history of the globe, and there is plenty of evidence of its having done so in the vast extent of some of the strata of the earth; not perhaps so often as Geologists at present believe. My own

idea is the strata are divided up too much, and that some of them have been deposited at the same time. Take for instance the strata now being deposited in the Atlantic Ocean, which we have been just considering. Here we have in the north, boulder clay, sand, and mud, with fossils from the Polar regions; in the east, sand from the desert brought down by the Congo and Niger, mud by the Nile, all with tropical fossils; on the west, fossils of the American type. These are deposited on different parts of this ocean where live different types of fish and mollusca. All this is taking place at the same period. Is it not possible for a Geologist finding a similar case, with perhaps a later strata deposited right across it, to conclude that the parts with tropical fossils were formed at a different period to that with Arctic fossils.

To sum up, we have the earth a collection of aerolites enveloped in steam, revolving round the sun and also on its own axis; gradually cooling down till the steam turns to rain, and the sun and moon and stars appear. In consequence of its revolution on its own axis, longitudinal fissures take place, through which igneous matter is forced up, forming mountains which in their turn form oceans and retard the ocean currents. These oceans are filled up with debris, forming land on a new portion of the earth's surface, thus altering the density of the earth and causing the earth to revolve on a new axis. Consequently a debâcle takes place, changing the whole face of the globe. This process is repeated at vast intervals, forming the different periods of stratification. Added to this there are minor local disturbances which complicate matters. This then is the problem for the Geologist to unravel.

REPORT OF THE COUNCIL.

THE Eighty-second Report, forming part I. of volume XII. of the Transactions of the Society, which was issued in January last, informed the members of everything of interest in the history of the Society down to the date of the Annual Meeting in November, 1895.

The depression of the mining industry of the County, which cuts off that great supply of practical Geological discovery from which this Society was so enriched a generation ago, still continues; but the work of the Society in the narrower limit to which it is thus confined has been steadily carried on during the past year.

The communication with so many other Geological and Scientific Societies, and the interchange of reports, the extent of which can be judged from the report of your Librarian, and which serves to make the library of this Society of such great value, has been maintained in full vigour.

Lectures were delivered in the Museum during the winter by Mr. A. K. Barnett and Mr. J. B. Cornish, but the Committee regret that the attendances were not more encouraging.

The thanks of the Society are due to these gentlemen and to Mr. J. H. Collins for his valuable work in the fossil museum; and also to Miss Hawkins for the present of a portrait of the late Professor Waterhouse Hawkins, which has been placed in the library; and also to those gentlemen whose donations appear in the reports of the Librarian and the Curator.

In connection with the suggestion contained in the address of the President at your last Annual Meeting, it was resolved

at the joint meeting of the Cornish Scientific Societies, which was held at Falmouth on the 26th August, that steps should be taken to obtain a complete resurvey of the County by the officers of the Royal Geological Survey, and a committee, consisting of the Presidents and the Secretaries of the several Societies, was appointed for the purpose, and the Secretary of this Society was appointed Secretary of that Committee. Your Committee fully recognise the importance of the work, and approve that it should be carried out under the auspices and authority of this Society.

The first "William Bolitho" Medal being ready for presentation, your Committee has resolved that it shall be awarded to Professor Robert Etheridge, F.G.S., in recognition that his age, his great attainments, and his life-long labours for the benefit of the science fully justify the selection. They are pleased to record his presence on this occasion.

With most sincere regret the Committee record the death of Mr. G. B. Millett, on the 17th September last. In common with many local institutions this Society had received the benefit of his patient and unselfish interest, and in common with them feels the extent of the loss sustained by his death.

Mr. Millett, a life member of the Society, was elected Hon. Curator in 1869, and Hon. Secretary in 1874, on the retirement of the late Mr. J. Hallett Batten, which office he held until his death, a period of nearly 22 years, and during the whole of that time personally discharged the duties of his position, which included the editing of three volumes of the transactions. In 1891, on the receipt of the legacy left by the late Rev. J. J. Carne which endowed the Curatorship, Mr. Millett was elected to that office, and the many responsibilities of the two appointments received his attention to the last.

The members are to-day asked to confirm the appointment of Mr. John Batten Cornish to the vacancies so caused.

By his will Mr. Millett has given to this Society the collection of fossils and other specimens got together by Mr. Tracy Millett and himself, with the cabinets in which they are preserved. A legacy which, apart from its value, shows well the kind

interest which he felt towards the Society. These cabinets with their contents are now in the passage of the Museum, awaiting the attention of the new Curator. They contain in addition to the fossils and other Geological specimens, a large number of objects which would be of interest to students of local Archæology; and Mr. Millett's family are quite willing that these should be presented to the Museum of the Penzance Natural History and Antiquarian Society, with which Mr. Millett was also intimately connected.

The Committee also regret to record the death of Mr. E. A. Wünsh, F.G.S., a man of wide knowledge and generous sympathies, whose especial eminence in Geology led him to take a hearty interest in this Society from his first coming to reside in Cornwall.

From among the hon. members the Society has lost two eminent men.

Mr. G. A. Daubrée, one of the most venerable representatives of natural and experimental science in France, died in May last, at the age of 82 years, having been an honorary member of this Society since 1875.

Professor H. E. Beyrich, of Berlin, died on the 9th July. He was elected an honorary member in 1888, at which time he filled the position of President of the International Geological Congress.

LIBRARIAN'S REPORT.

From 1st Nov., 1895, to 31st Oct., 1896.

THE following works have been added to the Library during the year:

I. TRANSACTIONS, JOURNALS, AND REPORTS.

Presented or purchased.

Adelaide. South Australian School of Mines and Industries, and Technological Museum. Seventh Annual Report, 1895. 8vo. Adelaide, 1895.

Australasian Association for the Advancement of Science. Report of the Sixth Meeting, held at Brisbane, Queensland, in January, 1895. 8vo. Sydney, N.S.W., 1895.

Boston. American Academy of Arts and Sciences.
Proceedings: New Series, Vol. xxii., May, 1894, to May, 1895, including Index. Royal 8vo. Boston, 1895.

Bristol. Naturalists' Society.
Proceedings: New Series, Vol. viii., part 1, 1895-96. 8vo. Bristol, 1896.
List of Officers, etc. ,, ,,

Buenos Aires. Museo Nacional.
Anales: Del Museo Nacional de Buenos Aires Tomo iv., (Ser. 2; t. 1.) Imp. 8vo. Buenos Aires, 1895.

California. State Mining Bureau.
Bulletin: Nos. 7 and 8 (sheets), showing by Counties the Mineral Productions of California for the years 1894 and 1895. San Francisco, 1894-95.

Camborne. Mining Association and Institute of Cornwall.
Transactions: Vol. iv., part 2. 8vo. Camborne, 1895.

Cambridge. Library Syndicate.
Forty-second Annual Report for the year ending December 31st, 1895. 4to. Cambridge, 1896.

Canada. Canadian Institute, Toronto.
Transactions: Vol. iv., part 2, December, 1895.
(Including Title-page and Contents of Vol. iv.)
Royal 8vo. Toronto, 1895.

——. Geological Survey of Canada.
Maps of the Principal Auriferous Creeks in Cariboo Mining District, British Columbia. By Amos Bowman.

Maps Nos. 364—372. With Notes.
,, of Nova Scotia; Sheets Nos. 25—38.
,, of Quebec; Eastern Townships Map.
,, of Ontario; Rainy River Sheet.

These Maps are to accompany the Vols. of the Society's Annual Reports in which they are described.

——. Geological Survey of Canada.
Contributions to Canadian Palæontology, Vol. ii., part 1. By Samuel H. Scudder. Royal 8vo. Ottawa, 1895.
Palæozoic Fossils, Vol. iii., part 2. By J. F. Whiteaves, F.G.S., F.R.S.C., etc. Royal 8vo. Ottawa, 1895.

——. Royal Society of Canada.
Proceedings and Transactions: Second Series, Vol. i.
Imperial 8vo. Ottawa, 1895.

Chicago. Academy of Sciences.
Bulletin: Vol. ii., No. 2. 8vo. Chicago, 1895.
Thirty-eighth Annual Report for the year 1895.
8vo. Chicago, 1896.

Cincinnati. Society of Natural History.
Journal: Vol xviii., Nos. 1—4, April, 1895, to January, 1896.
8vo. Cincinnati, 1895-96.

Colorado. Scientific Society.

Proceedings: (In separate pamphlets), viz.:

Occurrence of Tellurium in Oxidized Form, Associated with Gold. By Dr. Richard Pearce. Read April 1st, 1895.

The Dyke on the Columbian Vein in Ward District, Boulder County, Colorado. By Chas. Skeele Palmer and W. B. Stoddard. Read October 7th, 1895.

Concretions of Chalcedony and Opal in Obsidian, and Phyolite in Colorado.

Peculiar Geological Formations at the Head Waters of the Rio Grande, Colorado. By Horace B. Patton. Read November 4th, 1895.

The Nickel Deposits near Riddle's Oregan. Second paper. By W. L. Austin, P.L.D. Read January 6th, 1896.

Some Notes on the Occurrence of Uraninite in Colorado. By Richard Pearce. Read September 9th, 1895.

On Pearcite, a Sulpharsenite of Silver, and on the Crystallization of Polybasite. By S. L. Penfield, Read April 6th, 1896.

The San Miguel Formation. Igneous Rocks of the Telluride District, Colorado. By Whitman Cross. Read September 7th, 1896. 8vo. Denver, 1895-96.

Dorpat. Dorpater Naturforscher Gesellschaft.

Archivfür die Naturkunde liv, Ehst, und Kurlands. Serie ii., Band xi., lief 1. 8vo. Dorpat, 1895.

Sitzungsberichte: Band x., heft 3, 1894.
Band xi., heft 1, 1895.
8vo. Dorpat, 1894-95.

Schriften: viii. Synchronistische Tabellen über die Naturwissenschaftliche Journalliteratur, von 1650-1893. Von Professor Dr. Carl Schmidt.

Schriften: ix. Studien über Sexuellon Dimorphismus, Variation und verwandte Erscheinungen. Von Professor Dr. J. Kennell. Royal 8vo. Dorpat, 1895-96.

Dublin. Royal Dublin Society.
Scientific Proceedings: New Series, vol. viii., part 3, August, 1894.
New Series, vol. viii., part 4, September, 1895.
8vo. Dublin, 1894-95.

Scientific Transactions: Series ii., vol. v., parts 5—12, August, 1894, to January, 1896.
Series ii., vol. vi., part 1, February, 1896.
4to. Dublin, 1894—96.

Edinburgh. Geological Society.
Transactions: Vol. vii., part 2. 8vo. Edinburgh, 1895.

—. Royal Society.
Proceedings: Vol. xx., Sessions 1893—95.
8vo. Edinburgh, 1895.

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Bulletin: No. 123.—A Dictionary of Geographic Positions.
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No. 126.—A Mineralogical Lexicon of Franklin, Hampshire, and Hampden Counties, Massachusetts.
No. 128.—The Bear River Formation and its characteristic Fauna.
No. 129.—Earthquakes in California in 1894.
No. 131.—Report of Progress of the Division of Hydrography for the Calendar years 1893 and 1894.
No. 132.—The Disseminated Lead Ores of South Eastern Missouri.
No. 133.—Contributions to the Cretaceous Palæontology of the Pacific Coast: The Fauna of the Knoxville Beds.
No. 134.—The Cambrian Rocks of Pennsylvania.
8vo. Washington, 1895.

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"A Geological Reconnaissance across Idaho," by George H. Eldridge; "The Geology of the Road-building Stones of Massachusetts, with some consideration of similar materials from other parts of the United States," by Nathaniel Southgate Shaler; "Economic Geology of the Mercur Mining District, Utah," by J. Edward Spurr, with Introduction, by S. F. Emmons; "The Public Lands and their Water Supply," by Frederick H. Newell; "Water Resources of a portion of the Great Plains," by Robert Hay. Part 3, "The production of Iron Ores in various parts of the World," by John Birkinbine; "Iron and Steel and allied Industries in all Countries," by James M. Swank; "Reconnaissance of the Gold Fields of the Southern Appalachians," by George F. Becker; "Copper," by Charles Kirchhoff; "Lead," by Charles Kirchhoff; "Zinc," by Charles Kirchhoff; "Manganese," by Joseph D. Weeks; "The production of Tin," by Charles M. Rolker; "Aluminum," by R. L. Packard; "Bauxite," by Charles Willard Hayes; "Quicksilver," "Nickel," "Chromium," "Tungsten," "Antimony," by Edward W. Parker. Part 4, "The production of Coal in 1894," by Edward W. Parker; "Manufacture of Coke," by Joseph D. Weeks; "Origin, Distribution, and Commercial value of Peat Deposits," by Nathaniel Southgate Shaler; "Petroleum," by Joseph D. Weeks; "Natural Gas in 1894," by Joseph D. Weeks; "Asphaltum," by Edward W. Parker; "Stone," by William C. Day; "Soapstone," by Edward W. Parker; "Magnesite," by Charles G. Yale; "Clay," by Jefferson Middleton; "Technology of the Clay Industry," by Heinrich Ries; "Abrasive Materials," by Edward W. Parker; "Precious Stones," by George F. Kunz; "Commercial Development of the Tennessee Phosphates," by Charles Gustavus Memminger; "Sulphur and Pyrites," by Edward W. Parker; "Salt," by Edward W. Parker; "Gypsum," by Edward W. Parker; "Monazite," by H. B. C. Nitze; "Mineral Paints," by Edward W. Parker;

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Transactions: Vol. x., 1894-95.
(Including Title-page and Contents.)
Royal 8vo. Madison, Wisconsin, 1895.

II. GEOLOGICAL & MISCELLANEOUS PUBLICATIONS.

Presented by the Authors or other Donors.

Collins, J. H. Cornish Tin-stones and Tin-capels. By J. H. Collins, F.G.S. 8vo. Truro, 1888.
[Presented by the Author.]

A Catalogue of the works of Robert Were Fox, F.R.S., &c., &c., chronologically arranged, with notes and extracts, and a sketch of his life. By J. H. Collins, F.G.S. Crown 4to. Truro, 1878.
[Presented by the Author.]

Four centuries of Copper production in the West of England. By J. H. Collins, F.G.S., F.I. Inst., &c. 8vo. Falmouth, 1895.
[Presented by the Author.]

Fox, H. Photograph of Carzantic Quarry, Launceston. By Hayman & Son.
[Presented by Howard Fox, F.G.S.]

Hawkins, L. Photograph of the late Benjamin Waterhouse Hawkins, F.L.S., F.G.S.
[Presented by his daughter.]

Holland, Thomas H. On the Acicular Inclusions in Indian Garnets.

On the Origin and Growth of Garnets and of their Micropegmatitic Intergrowth in Pyroxenic Rocks. (With Plate.) By Thomas H. Holland, A.R.C.S., F.G.S. Royal 8vo. Calcutta, 1896.
[Presented by the Author.]

Holland, T. H., and Saise, W. On the Igneous Rocks of the Giridih (Kurhurbarce) Coalfield and their contact effects. By Thomas H. Holland, A.R.C.S., F.G.S., and Walter Saise, A.R.S.M., D.Sc., F.G.S. (With Maps, Plates, and Wood Cuts.) Royal 8vo. Calcutta, 1895.
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[Presented by the Author.] 8vo.

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[Presented by the Author.]

CURATOR'S REPORT.

NOVEMBER, 1896.

DURING the past year the following specimens have been added to the Society's Museum:

NAME AND LOCALITY.	DONOR.
Spirifera disjuncta from Delabole . .	J. D. Enys, Esq.
,, ,, ,, ,, . .	
,, ,, ,, ,, . .	
Slab of Greenstone, New Zealand . .	Rev. W. Colenso.

TREASURER'S STATEMENT, 1895-96.

Dr. *The Treasurer in Account with the Royal Geological Society of Cornwall.* **Cr.**

November 8th, 1895—	£	s.	d.
To Balance	7	12	10
November 10th, 1896—			
,, Ordinary Subscriptions and Arrears	63	0	0
,, Donation per H.R.H. The Prince of Wales ...	20	0	0
,, One Year's Dividend on £1500 Midland Railway 3% Debenture Stock, less tax	43	10	0
,, Balance	5	2	10
	£139	5	8

November 10th, 1896—	£	s.	d.
By Rates and Taxes	0	14	6
,, Housekeeper's Salary	20	0	0
,, Curator's ,, ...	50	0	0
,, Insurance Premium	2	12	9
,, Books, Binding, &c.	39	12	0
,, Coals, Gas, &c.	8	13	3
,, Repairs to Buildings	4	7	5
,, Palæontographical Society	1	1	0
,, Sundry Expenses, viz.—			
Advertising, Printing, Stationery, Postages, &c.	12	4	9
	£139	5	8
,, Balance due to Treasurer	5	2	10

T. ROBINS BOLITHO, *Treasurer.*

PENZANCE, *November 10th, 1896.*

LIST OF PAPERS READ AT THE ANNUAL MEETING

10th November, 1896.

1. Address of Professor Etheridge on receipt of the "William Bolitho" Medal.

2. The Foraminifera of the Pliocene Beds at St. Erth as compared with other deposits. By F. W. Millett, F.G.S.

3. The Morte Slates and their bearing on the Cornish Devonians. (Abstract.) By F. J. Stephens.

4. On an altered Ashbed at Penryn. By F. J. Stephens.

5. The Submarine Forest Bed at Maenporth. By S. Roberts.

6. Notes on Cornish Fossils. By J. H. Collins, F.G.S.

ADDRESS BY PROFESSOR ETHERIDGE

ON RECEIPT OF

THE "WILLIAM BOLITHO" MEDAL.

(Read November 10th, 1896.)

I AM deeply sensible of the unexpected honour which the Royal Geological Society of Cornwall has to-day conferred upon me, by awarding me the first "Bolitho" medal, an honour wholly unexpected and greatly valued; and it is an additional pleasure that I receive it, Sir, from your hands, many years ago my colleague in Her Majesty's Geological Survey.

I need not say how highly I appreciate this distinction. I shall treasure its possession still more highly, being the first recipient of the medal awarded through the vote of your Council and the munificence of its founder. Throughout a lengthened life I have been permitted to study nature and natural science, as well as the labours and works of the great and good who have contributed to the study and advancement of the two kindred and incomparable sciences, Geology and Palæontology, and this recognition and reward for patient

yet pleasurable labour and research comes gratefully to the recipient of to-day's honour, and with it the feeling and stimulus of renewed energy.

The labour of nearly fifty-one years has been guided by two incentives, a love for my work and devotion on one hand, and secondly from a sense of duty, during the many years I enjoyed the confidence of my two distinguished chiefs, Sir Roderick Murchison and Sir Andrew Ramsey, when attached to H.M. Geological Survey, and classifying the extensive selection of invertebrata in the Museum of Practical Geology, as well as giving my annual course of forty demonstration lectures on Palæontology to the students of the Royal School of Mines.

In 1882 I was solicited by the trustees of the British Museum to accept the position of assistant keeper in the Geological department, associated with my friend and colleague, Dr. H. Woodward. I have every reason to be deeply thankful for the great advantage derived from the special study of that vast collection during the duty of carrying on the work of the department.

Time and labour devoted to special work, however arduous, is advanced by the belief that it is or may be useful to and valued by others. It is, however, made lighter by the recognition of those who value self-sacrifice for science sake; no labour is too great to be devoted to those duties we have to perform, either on behalf of the student whose future place in life may possibly depend upon and be influenced by his teachers, or in those public

duties we may be called upon to perform, as servants of the state in civil or other departments.

We know how vast is the mass of Geological and physical research and learning hitherto accomplished, and yet how insignificant in comparison with that which remains to be done or awaits us for further discovery. The history of the igneous and stratified rocks over the earth's surface, as partly known to us through past time and research, merely shadows forth the great problems yet to be solved in the future. These will not be revealed to us except and unless through constant, continued, and patient research.

Nineteen years ago, through the influence of your late able President, Sir W. Smyth, then my colleague and esteemed friend, your Society and Council, at his request, placed a sum of money at my disposal, to be devoted to purchases and other purposes, as well as for the classification of the new addition to your museum collection. He was pleased to believe, and announced in his Presidential address, that the stratigraphical collection and arrangement for its size was for study and use scarcely surpassed, upwards of 1,000 characteristic species being added and named.

By adding my name to the roll of distinguished recipients for work done is a recognition for devotion to our incomparable science, and causes me to feel and hope that I am worthy of this distinction, though I know I fall short of such consideration and honour. I still hope to merit and

repay through work yet undone or to be done, by aiding others to spread abroad those truths of natural and physical science, as taught through Geological and Palæontological research.

This recognition and award come at an age when the natural diminution of physical strength confines us to the study and home, but dreams and remembrances still carry us again over those hills and valleys whose history and structure constitute the highest charm of our incomparable science.

This reward for a long life of research and labour, associated with duty, comes gratefully to me, and with it the feeling that however much may be wanting, the recipient of to-day's honour has not been forgotten and will never forget.

THE FORAMINIFERA OF THE PLIOCENE BEDS OF ST. ERTH

IN RELATION TO THOSE OF OTHER DEPOSITS.

By Fortescue William Millett.

(Read November 10th, 1896.)

In the year 1887, when the Geologists' Association visited St. Erth, in order to give the members some idea of the nature of the deposit, its limited extent, its isolation, and the character of its organic contents, I ventured to suggest that a similar result might have been attained if in far-away times, before the so-called "Head" had spread itself over the district, some large ship returning from southern Italy in ballast, had been stranded and gone to pieces at St. Erth.

Subsequent researches show more and more the close relations between the St. Erth foraminifera and those of Italy. In part 2 of the "Monograph of the Foraminifera of the Crag," by Professor T. Rupert Jones,[1] the words "Pliocene of Italy and St. Erth" appear over and over again in the list of localities for the crag species.

But with these lowly organisms a mere comparison of lists of species will not perfectly show the relations between different faunas. The endless variations

1 Palæontographical Society, 1885.

of the foraminifera if carefully noted afford valuable elements for comparison. To clearly indicate these variations we require space of three dimensions. The typical forms may be regarded as so many points in space, and from each of these types radiate in all directions individuals which, in receding, gradually lose the characters of the parent, and as gradually assume those of the neighbouring type in whose direction they chance to radiate.

As an illustration take the form *Discorbina turbo*, in the crag deposits of the Eastern Counties; this varies towards the form of *D. rosacea*, whilst at St. Erth and in the middle miocene of Sicily the variation is in the direction of *Rotalia Beccarii*. This variety has been named by Seguenza[2] *Discorbina solarium*.

Again, *Rotalia Beccarii* appears in the crag only in its typical form, smooth on the upper and sculptured on the lower surface of the test, whilst at St. Erth and in the upper miocene of Sicily it is represented also by the larger and more fully developed *Rotalia punctato-granosa* (Seguenza), which is sculptured both on the upper and the lower surfaces, and forms a stepping stone to the species *R. Schroeteriana*, *R. Papillosa*, etc.

Recently Dr. Schacko, of Berlin, has found specimens of the St. Erth species *Bolivinia gibbera* in the pliocene of Girgenti, South Sicily, and I am indebted to his kindness for an excellent drawing of one of his specimens, which is in all respects

2 Atti R. Accad. Lincei, Ser. 3, vol. vi., 1880, p. 64, pl. vii., fig. 9.

identical with the figure of the species in the Transactions of this Society for the year 1895. Dr. Schacko's drawing is from a specimen rendered transparent by Canada balsam, consequently the internal structure of the test is well shown. It is interesting to note that this species, hitherto known only from St. Erth, should have turned up in the pliocene of Sicily.

With regard to the genus *Faujasina*, which is the predominant partner in the St. Erth deposit, O. G. Costa in his "Paleontologia del Regno di Napoli,"[3] under the name *Faujasina carinata* d'Orb. figures a form which looks like an unsymmetrical *Polystomella*. He describes the periphery as being carinate, but in the figure it is shown distinctly rounded. The given localities are Pozzuoli and S. Alesandro in Ischia. Costa appears to have been in the habit of writing rather hurriedly, and there are many discrepancies between his descriptions and the accompanying figures and even, as shown by Signor Fornasini, of Bologna, between the figures and the original specimens from which they were drawn. It would be rash at present to accept Costa's form as evidence of a resemblance between the St. Erth and the Italian foraminifera. Dr. Fornasini is now engaged in the useful work of revising Costa's determinations of specie from the original specimens themselves, and it is to be hoped that some day he will be able to enlighten us on this particular subject.

3 Atti Accad. Pontaniana, vol. vii., fasc. 2, 1856, p. 269, pl. xx., fig. 13.

Faujasina first appears in the upper cretaceous beds of Maestricht, then it appears in a different form in the eocene of the environs of Paris—very rare in both formations. Skipping all the intermediate strata it next appears in both forms and in extraordinary abundance in the pliocene of St. Erth. The genus is so distinct and so easily identified that it can hardly have been overlooked if it existed in any other deposits.

From the foregoing it will be seen that the affinities of the St. Erth foraminifera are with those of Italy rather than with those of the crag of England.

ABSTRACT OF A PAPER ON "THE MORTE SLATES AS DESCRIBED BY DR. HICKS."

By Francis J. Stephens.

(Read November 10th, 1896.)

Dr. Hicks, the present president of the Geological Society, has thrown a good deal of light upon the real succession of the so-called Devonian rocks of North Devon.

Recently Dr. G. J. Hinde, F.R.S., and Mr. Howard Fox, F.G.S., have made important discoveries of radiolarian chert of carboniferous age near Barnstaple. North of Barnstaple to beyond Ilfracombe the rocks have been hitherto supposed to be a conformable succession of most, if not all, of the upper, middle, and lower Devonian rocks. Dr. Hicks, however, has proved the hitherto unfossiliferous morte slates, classified usually as middle Devonian, to contain what he considers to be Silurian fossils. Thus if he is right there is a patch of much older rocks sandwiched between upper and middle Devonian formations.

Rocks usually classified as the equivalents of the morte slates occur in South Devon, and the

rocks near Rame Head have also been doubtfully suggested to be of the same age. Briefly the morte slates are described as greenish gray in colour, rather silky in texture, and occasionally very quartzoze. They also apparently contain much iron.

Similar rocks occur near Tintagel and in other parts of Cornwall.

The fact of these morte slates (if they are proved to be older) having been brought up by a large thrust fault should act as an incentive to Cornish Geologists. Many great faults are known to pass through the Cornish killas, and it is suggested that there may be rocks of much greater age exposed amongst the Devonian rocks of Cornwall in much the same way. And the fact that the morte slates (which have been considered unfossiliferous for over 50 years) now produce an ample fauna should also prove a great encouragement to Cornish Geologists. It is quite probable that some of the Cornish rocks, now thought to be barren, may also in the end produce fossils.

ON AN ALTERED ASHBED AT PENRYN.

By Francis J. Stephens.

(Read November 10th, 1896.)

At the joint meeting of the Scientific Societies of Cornwall, held at Falmouth this year (1896), the writer had the honour of representing this Society with a paper[1] in which a more or less volcanic origin was suggested for parts of what are known as the "Falmouth slates." In this paper it was mentioned that several varieties of igneous and metamorphic rocks occurred between Boyer's Cellars on the Penryn Creek, and the Green Bank Pier and Flushing. It is now proposed to give a more detailed account of these.

In R. Thomas's "History of Falmouth,"[2] published in 1827, there is a short account of some of these rocks which, however, are all included under the unsatisfactory name of elvans. Mr. J. H. Collins, F.G.S., has described the Flushing rock[3] and also the quartzites, but with these exceptions no other writer has mentioned them.

The great bulk of these "Falmouth slates"

1 "On certain Rocks in the Falmouth District." *R.C.P.S. Report, 1896.*

2 R. Thomas.—"History of Falmouth," 1827. Falmouth.

3 J. H. Collins, F.G.S.—"On the age of the Rocks of Central and West Cornwall." *Transactions Royal Institution of Cornwall, 1881.*

consist of variegated types of rough gritty and occasionaly silky argillaceous slates, which are generally more or less veined with quartz. They are well exposed near Penryn in road cuttings, and in the foreshores of Penryn Creek. A certain interesting ribboned variety is very frequent. Dr. Boase, in 1831,[1] described the slates south of Penryn as a decomposed hornblende slate. Sections of the rock taken from these cuttings and the foreshore show, however, no hornblende, although near the granite slight chiastolitic indications appear, while in close proximity the slate becomes very micaceous.

The slates and rocks to be described are all apparently interbedded, and have the normal N.E. strike of the district.

At Flushing a large mass of rock has been extensively quarried Mr. Collins[2] has called this rock a mica trap, and has included it amongst others described by him as a group. It should, however, be remarked that the Flushing dyke, if a mica trap, is distinctly different from those which occur at Pendennis Point,[3] Mawnan Shears,[4] and at Penryn.[5] Mr. Collins considered that the mica traps were intrusive amongst the slates, and probably were ejected at a slightly earlier period than the formation of the granite.[6]

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1 Dr. Boase.—"Geology of Cornwall." *R.G.S.C., 1832.*

2 J. H. Collins, F.G.S.—(See page 49.)

3 *R.G.S.C., 1893.*

4 Sir H. De La Beche.—Report, 1837.

5 R. N. Worth, H. Fox, etc.

6 J. H. Collins, F.G.S. -(See page 49.)

Succeeding the Flushing dyke, on the Trefusis side, is what appears at first sight to be a large band of indurated slate. This is full of cavities, some of which are partially filled with a soft white decomposed clayey material, and what seems to be oxide of iron. This gives it when fresh an amygdaloidal structure. The whole of the mass is much jointed, breaking under the hammer into regular blocks. The colour is almost white, with frequent small red specks disseminated over its surface. It extends for nearly ten yards to the south, but unfortunately its junction with the "mica trap" is not seen, owing to the pier which at this point entirely covers the foreshore. To the south the slates are much disordered, and are traversed by the main lode of the Wheal Clinton lead mine, long since abandoned.

The rock in the quarry behind the pier is of a light sage green colour, rather schistose in its character, in parts much jointed and compact rather than crystalline in structure. The Pendennis mica trap on the contrary largely consists of mica, the flakes being often of large size, and sections of the two rocks show a very different appearance. The Flushing quarry produces a good road metal. which might be used far more extensively than it is.

This rock is again exposed south of Green Bank Pier and behind Middle Terrace. The strike should carry it through what is known as the Town Quarry, but no trace of it here appears.

On the summit of Beacon Hill, on the Falmouth

side of the creek, is a large mass of white quartzite which has also been described by Mr. Collins and other writers. This is uncommonly pure in its composition, being almost entirely composed of a dazzling white quartz, occasionally containing green chlorite, sometimes hard and crystallized like the quartz. Its relations to the surrounding rocks are very obscure, although quarrying has produced a very fine section of the quartzite itself. It shows no trace of any former stratification, but large "breast heads" irregularly cross it at rough right-angles. This quartzite again appears in Tregenver farm-yard, and on the opposite side of the valley at Mongleith; but in both these places it is associated with a rich marly clay, which may be caused by the decomposition of the associated felsite to be described.

About 100 yards north of the Green Bank Pier the quartzite appears again in the foreshore; but here it is almost black in colour, and on both sides is associated with a greenish felsitic rock, not unlike the Flushing dyke. It contains, however, no mica at all. This also is succeeded on the south towards Green Bank by an apparently much indurated slate. In places this latter is greatly decomposed, and of a deep orange colour. It shows no structure in the harder parts, although it weathers into rectangular blocks.

On the opposite side of the creek, south of Little Falmouth, the quartzite is again exposed; but no good section can be obtained, owing to a

sea wall which has been built up along most of of the foreshore.

North of the quartzite a series of variegated slates, which are very quartzose and much contorted, continue to near Boyer's Cellars. These slates when decomposed often contain large patches of spotted and red marly clay.

Immediately south of Boyer's Cellars, where the cliffs have been cut back to form a yard, the slates are very hard and compact, as well as blueish in colour. A mineral lode here has been exposed, and an old adit is still to be seen which was formerly driven upon its course.

Westward of Boyer's Cellars, just where the cliffs curve round into Turnpike Creek, is an interesting and new type of rock. A dark greenish band about 20 feet wide is here met with. It is connected with mineral veins containing iron oxide and a loose friable quartz, which ramify in what appear to be the jointed structure of the dyke. Variegated slates again succeed upon the northern side. At first sight this rock appears to resemble an impure serpentine when newly broken. Along the sides which are not distinctly marked it assumes a somewhat schistose form, and gradually but somewhat irregularly blends into the succeeding shales on either side. In the centre of the dyke, where many veins of quartz fill the joints, it is exceedingly hard, and almost resembles a basalt.

Two sections have been prepared of this rock, and it has been submitted to Mr. J. H. Teall, F.R.S.,

who, with reserve, considers that it may be an altered volcanic ash. This view has been confirmed by other Geologists. Both sections contain much felspar.

Towards the sides the mass has a somewhat silky half-stratified appearance, and when freshly broken the colour varies from a dark olive green to a light sage colour. On the north it alternates with bands of yellow, grey, and blue slates, and the alternate bands much resemble the main mass.

The whole dyke appears to have been subjected to a very great pressure, which has consolidated its probable loose original structure into the compact appearance it now presents. At the same time there are many signs of alterations in the mass itself. The quartz infillings and the opening of fissures, now filled with iron and other mineral, point to a leaching out and refilling of some of the earlier constituents of the ash. Especially is this the case in those parts of the formation which are nearest the centre, and may therefore be naturally supposed to have had less admixture with muddy sediment at the time of its deposition.

The continuation of this ashbed is to be seen near the head of what is known as Frenchman's or Deadman's Cove,[1] on the opposite side of the Penryn Creek. Westward it may be again observed in Penwerris farm-yard, and in the railway cutting north of Tregenver; but in all these exposures it is but a few feet wide.

1 Names which have a certain unpleasant association with the great French war. Dead prisoners of war are supposed to have been buried here.

It will be thus seen that there are at least two types of rock within half-a-mile which are distinctly of different origin to the surrounding slates, while there are associated with these other rocks whose origin cannot be considered as purely sedimentary. From Boyer's Cellars southward we have first a rock now presenting a very compact appearance, not unlike an impure serpentine, which was probably in the first place an interbedded ash, consolidated and altered since its deposition by conditions of great heat and pressure.

Immediately succeeding are variegated slates showing irregular cleavage, and freely filled with patches and veins of quartz. Then a broad band of hard felsitic rock or trap which is associated with and apparently encloses a mass of black quartzite farther west of a pure white colour. Succeeding these we have a decomposed mass of rock, showing no structure in the hard parts, but outwardly splitting into rude blocks.

South of the latter are broken and altered slates, while last of the series is the Flushing dyke, greenish in colour, very compact, and containing a little mica, which gives it a somewhat schistose appearance, and associated with this a hard indurated rock, full of amygdaloidal cavities. Beyond this last the slates gradually resume their general appearance and character.

It has been proved that the effect of great pressure and contortion upon various types of ancient volcanic rocks has been to alter them very

considerably.[1] Especially great is this alteration when the metamorphism of a great series of rocks, consequent upon the formation of granite, is taken into account.

The age of the Falmouth slates is not definitely known, but it is certain that the Stithians granite was formed long after their deposition. We have as yet no proof of any direct volcanic rocks in the Falmouth district amongst the slates, and we may consider that the ash, etc., under notice were the indirect products of a submarine vent or vents, probably intermittent in character and contemporaneous with the deposition of the slates.[2]

Mr. Clifton Ward, F.G.S., in a series of observations on the results of metamorphism in the slate country surrounding the Skiddaw granite, discovered that many volcanic types of rocks there exposed were originally very different.[3] Thus he found that a certain hard felstone was originally a fine-grained ash, and that another white weathering felstone, outwardly showing no structure, was formerly a coarse brecciated ash. What was in the first place a thin vesicular lava was changed into an amygdaloidal rock, charged throughout with added material, and a bed of loose volcanic dust became a fine-grained trap. This it is quite probable is what has happened to the rocks under notice, with of course considerable local

1 PROFESSOR JUDD.—"Volcanos." RUTLEY.—"Study of Rocks," etc., etc.
2 DE LA BECHE.—"Report," etc.
3 J. CLIFTON WARD, F.G.S.—"Granitic and Metamorphic Rocks of the Lake District." *Q.J.G.S.*, *1875*.

modifications, and probably none of the Penryn Creek types can be really considered as intrusive amongst the slates, but are in reality a complicated series of interbedded ashes, lavas, and tuffs, which have assumed their present appearance under conditions of great heat and pressure, resultant upon the formation of the granite at a great depth.

The late Mr. R. N. Worth,[1] F.G.S., described many very similar rocks in East Cornwall, and suggested that they were of the same age as the Ashprington series of volcanic ashbeds, volcanic tuffs, and lavas. These latter rocks are of middle Devonian age, and it is of course possible that both in East and West Cornwall we may have representatives of these, which are typically developed in the South Hams district, near Dartmouth.[2]

There is a rock very similar to the Boyer's type exposed at the eastern corner of Swanpool Cove, while between the Hotel Beach and the Pendennis mica trap another narrow band of fine-grained felspathic trap, much traversed by cross-joints, also occurs. This latter is seen on the harbour side, about 300 yards from the Eastern Breakwater on the Pendennis side. The slates here are of the same variegated character, but the hard gritty bands forming Trefusis Point (not unlike the Rosemullion grits)[3] appear to intervene between two series.

1 R. N. WORTH, F.G.S.—"Igneous Rocks of S.E. Cornwall and their stratigraphical value." *Royal Inst. Corn., 1886.*

2 A. CHAMPERNOWNE, F.G.S.—"Papers on the Ashprington Series." *Q.J.G.S., 1880. Geol. Mag., 1891.*

3 *P.J.S., R.G.S.C., 1893.*

THE SUBMARINE FOREST BED AT MAENPORTH, NEAR FALMOUTH.

By S. Roberts.

(Read November 10th, 1896.)

The subject of submarine forest beds is by no means a new one to you. They have been frequently observed and minutely described by many eminent Geologists, and their occurrence around the Cornish coast is familiar to most of you, and my apology for inflicting this paper upon the patience of this meeting must be that what I have to describe happened very recently, and under peculiarly fortunate circumstances.

I fear that anything I may advance will add but little to what is already in your possession; but if it serve to revive the interest in the subject, my end will have been accomplished.

The allusions to these forest exposures of Cornwall are to be frequently met with in the Transactions of this Society, and before furnishing you with my own observations, I will, with your permission, draw your attention to a few of the more important notices.

Mr. J. Carne, in vol. vi., page 230, of the Reports

of the Royal Geological Society of Cornwall, speaks of the submarine forests of Mount's Bay. Dr. Boase explored that on the beach between Penzance and Newlyn, and Mr. J. Carne continued his researches eastward to Marazion. They describe the prevalence of trunks of trees and other evidences of an ancient forest growth.

In vol. vii., page 35, Mr. S. R. Pattison describes the submarine forest deposit of Maer Lake, near Bude Haven. He there found trees at a depth of twenty feet below the surface, with which were embedded bullocks' horns, some of which were four feet long and twenty inches in circumference. He also found a stag horn five feet long.

In vol. vii., page 185, Mr. R. Q. Couch speaks of the forest beds between Plymouth and Mount's Bay, and from St. Ives to Hartland Point. These contain identical vegetable and animal remains, deer and bullocks' horns being prevalent.

Mr. J. J. Rogers, in vol. vii., page 352, offers his evidence as to similar deposits found by him in the Cober Valley.

In vol. ix., page 98, Mr. T. Cornish speaks of the presence of peat beds containing hazel nuts and kindred vegetation, lying beneath surface mould, clayey shingle, and water-worn stones.

Mr. W. A. E. Ussher examined the submarine deposits of the Camel estuary, and in the Journal of the Royal Institution of Cornwall Mr. N. Whitley mentions those of Maenporth as containing wood and hazel nuts.

Sir H. De La Beche in his chapter on submarine forests says: "that at Maenporth, between Mawnan and Falmouth, has been described by Rev. Canon Rogers, who there noticed the stump of an oak in the situation in which it grew, the roots, as usual, running amid peat which bears evidence of having been formed in marshy ground, and containing, he considers, the leaves and roots of the 'Iris pseudacorus'—the common yellow flag—now growing in the adjacent marshes."

As far as I can gather, no animal remains have hitherto been discovered in this deposit.

Judging from the similarity in the constitution of these forest areas, both as regards their fauna and flora, one seems justified in attributing to them the same geological age, and that their presence, position, and chemical condition, were produced by similar physical agencies.

On Friday, 20th December, 1895, having heard that Maenporth beach was exhibiting abnormal signs of disturbance, incident upon the recent tempestuous weather, I proceeded thither. For several days previous to this date, there had been a succession of easterly and south-easterly gales, which had been instrumental in removing enormous quantities of sand from the beach. It would appear that the sand had not been conveyed to any great distance seaward, but had been deposited as a huge temporary bar, silting up the mouth of the cove, somewhere in the region of low-water mark at spring tide. So great had been the ravages

of the surf, that much of the sand normally reposing at and above high-water mark had been dislodged, and the soil, with the turf growing upon it, adjacent to the high road, had also been torn away.

At the base of the dip of the beach, the sand had totally disappeared, especially at its northern and southern extremities, probably owing to the swirl and eddying of the water, rebounding from the rocks, being greater there. This action would, I think, be naturally less in the middle part of the beach.

There was an apparent gentle rise in the sand towards the central part. At the southern extremity there lay exposed a bed of brown—almost black—soft matter extending some sixty or seventy yards towards the middle of the beach. On treading on it I was struck with the springy and spongy character of it. Proceeding to examine the mass, I found that what at first appeared to be simply a bed of brown mould contained something far more interesting. There was a number of trees lying in various directions and positions; some of them from twelve to twenty feet in length that could be traced, but which were probably much longer, as some of them slanted downward at one end into the mould. I calculated that in some instances they reached a diameter of two feet, though many—and I concluded they might have been the detached boughs—were considerably less. They all yielded readily to the touch, and it was easy to detach portions from the parent stems.

One log had been shifted from its former resting place, and had been carried high up on to the beach. It was about six feet in length, and some ten inches in diameter. It was of a pink or reddish colour, and resembled pine wood. The wood would cut lengthwise, as one might cut soap or cheese. The grain was well preserved. Of course it was all waterlogged, and saturated with moisture throughout. Some of the timber was nearly black, and some of a reddish colour. Speaking cautiously, I should say that oak, pine, alder, willow, and hazel were among the varieties represented.

Having come unprepared to effect excavations, I was at a loss to sink to any depth into the peaty mass, but fortune, sometimes propitious, relieved me from my dilemma, by sending me a carter with his team on to the beach. I requisitioned his spade, and for a brief period was enabled to explore beneath the surface. The result was gratifying, and amply repaid the little labour expended.

I was anxious to ascertain the depth of the mould, but, having penetrated some three feet below the surface, I seemed very far short of the bottom. The most important find was a jaw-bone, which lay close to a large prostrate trunk of a tree. It was about one foot in length, and set in it in perfect order were five large teeth—the whole set—all molars, well preserved with labyrinthine crowns. Another similar molar presently turned up, probably once the occupant of the fellow jaw. The jaw was in a semi-fossilized condition.

I have not ventured, on my slender knowledge of anatomy, to locate the jaw to any particular animal, but per favour of Mr. F. J. Stephens it was submitted through Dr. Hinde to Mr. Woodward, who inclined to the opinion that it was that of a small horse. The modern horse, I believe, possesses six molars, this has only five. So we may take it that if of a horse, of an ancient one.

A scientific friend at Falmouth having examined it regarded it as differing from the jaw of the modern horse, and, being lately in Munich, he consulted Professor Zittel's work on palæontology, and there found a description and diagram of what he considers the exact counterpart of the Maenporth fossil, having assigned to it the euphonius name of "Prodremotherium elongatum," and this is a small extinct horse.

A few days before my visit a workman had found the antler of a deer in the same area, but not having seen it I cannot describe it. Both the jaw-bone and the antler are now in the possession of Mr. Robert Fox, of Grove Hill, Falmouth. Assuming the decision of the experts as to the jaw being tenable, we can safely assign to the submarine forests if not a great geological age, yet a very advanced historical one.

In excavating I found the mould to be of the same colour throughout, it emitted a powerful odour of sulphuretted hydrogen which was almost intolerable. In this mould I found the remains of aquatic plants, the impress of the leaves, stems,

rootlets, and flags being very marked. Hazel-nut shells, hazel twigs with the bark on, as well as fir cones partially deprived of their seeds, were abundant. These were so compacted together that, when removed, their prints were well-defined in the mould.

Although no exposure of the bed was visible in the middle of the beach, I have reason to believe it is continuous from one side to the other.

On the north side there is an adit which discharges the water from the two valleys uniting at Maenporth. At the period I speak of this stream poured forth an unusual volume of water, and issued from the aqueduct with such considerable force as to denude its bed of the sand, leaving exposed a bed of mould with trees embedded as on the south side.

No doubt a rich return might accrue by examining the valleys mentioned higher up, as the submarine forest bed under the beach is in all probability only the continuation and termination of a larger and similar area underlying the valleys.

NOTES ON CORNISH FOSSILS.

By J. H. Collins, F.G.S.

(Read November 10th, 1896.)

IV. SOME NOTES OF PROGRESS.

(*a*) The Working Catalogue.—This has now reached number 1030, but a great many more specimens have been provisionally labelled and fixed on tablets for better preservation and more convenient study.

(*b*) New Fossils of the North Coast.—The Cornish fossils presented to the Society during the past three years, by Mr. Howard Fox, F.G.S., are mainly from the north coast between Padstow and Bedruthan, an hitherto almost unworked region. They occur chiefly in a moderately hard dark blue slate, and are for the most part completely pyritized and in a high state of preservation, as regards the external form, although there is very little of structure to be made out. In some places the curious bodies known as Styliola (903)[1] and Tentaculites (415, 1024, etc.) are very abundant, and there are many species of Cephalopods, among

1 The numbers appended are those attached to the specimens referred to, now on view in the table-cases of the Lower Museum.

which the following have been more or less certainly recognized, viz.—

Agoniatites transitorius (1028),
Anarcestes latiseptatus (1029),
Anarcestes Noeggerathai (1035),
Bactrites (or Orthoceras) gracilis (973),
Bactrites Budesheimensis (1034),
Mimoceras compressus (1036),
Orthoceras Cochleiferum,
Tornoceras globosus (1027),
Tornoceras simplex (1030),

Several specimens of a remarkable little discoid coral, closely resembling if not absolutely identical with the Microcyclas simplex of Sandberger (974—975), have also been found.[1]

The presence of a little shell resembling Cardiola retro-striata (903, 891, 415) has been supposed to indicate that the beds referred to are of upper Devonian age, but the general appearance of the Cephalopods and corals above referred to seems to me rather to suggest that they belong to the upper part of the lower Devonians, and are correlatives or nearly so of the Orthoceras (Cephalopodien) Schiefer, of Germany, and in this opinion I am supported by my friend, Mr. Upfield Green, F.G.S.,

1 *Microcyclas simplex* (Sandberger). A small oval coral 12 x 5 m.m. in size, with twenty tolerably coarse simple stellate lamellæ of equal size, converging in a shallow depressed cup, resembling Trochophyllum of Edwards and Haime (*Polyps. foss. des. terr. pal.*, page 350), but is depressed instead of conical, and I therefore refer it to Microcyclas of Meek and Werther, although the lamellæ are not bifid, and no main lamella is clearly perceptible. ". . . . . occurs in lowest beds of lower Devonian." *Sandberger Entw. der Unteren, Abth. des Dev. Syst. im. Nassau*, Wiesbaden, 1889.

who has a very intimate knowledge of the lower Devonians of Coblentz and Nassau.

(*c*) ADDITIONAL NOTES ON PETRAIA.—I have had the advantage of examining a number of beautiful casts of Petraia brought from the lower Devonians of Coblentz by Mr. Upfield Green, and among them is one which very closely resembles the P. minimus described in a former paper (Trans. xi., p. 652 and plate 13, figs. 7 and 8). Another form from the Siechhausthal, near Coblentz, of which I have seen several specimens, has a general resemblance to P. pluriradialis (*ibid.* p. 650), but the "stem" is much shorter. There is, however, one difference of a somewhat remarkable character in the form of the base of the calyx, always a characteristic feature in this genus. All the Cornish Petraias I have examined exhibit in this part more or less of bilateral symmetry; but in the specimens now referred to the interspaces of the characteristic radiating lamellæ (represented in the casts by radiating ridges) are so developed as to form a sort of cross in the bottom of the calyx, dividing it into four areas, of which what may be called the anterior pair is somewhat larger than the posterior pair, the double or "keyhole" ridge of the cast being longer and more prominently developed than the other three main ridges. I have again examined our large suite of Cornish Petraias, but so far I have only detected mere traces of this cruciform arrangement. These occur in certain specimens of Petraia gigas (105, 240, 242), a

species to which the German fossils present but little resemblance otherwise.

These interesting German fossils, although they are merely casts in a fine-grained sandstone, tell us something about the life conditions of Petraia, unless I am very much mistaken. The cavity which represents the former substance of the fossil is in some instances incrusted with vermiform bodies, something like serpulæ. But as there could have been no cavity when the corals were originally buried in the sandy mud, I can only suppose that the "worms" existed within the substance of the coral itself, and that they had even then some form of "shell" which was composed of inorganic substance, traces of which remain, now that both coral and worm have disappeared. This association of "worm" and "coral," although not constant, recalls the similar association in the genus Pleurodictyum.

(*d*) Fish Fragments.—The fragmentary character of the numerous fish remains, still to be found in the Society's collection, is at times exasperating, yet they are not without interest. A good bit of work has been done in cleaning them, fixing on tablets and labelling, so as to facilitate their further study. By the skill of Mr. Upfield Green a part of a very large plate, with attached spine, has been worked out of its matrix. It is probably the dorsal plate of the Pteraspis (Scaphaspis) Cornubicus, of Ray-Lankester; the plate when complete must have been ten or twelve inches

long, the spine not less than three or four inches, and the whole fish at least three feet. Another spine (690) must have been even longer; but this is the largest plate of which we have evidence at present. This fossil, a small head-shield of a fish closely resembling Anchenaspis Egertoni, and a few other interesting objects I propose to sketch hereafter, so as to make up a plate of "fish fragments" for the next part of our Transactions.

(*e*) THE TRILOBITES.—The specimens are very numerous, but with a very few exceptions they are fragmentary and greatly distorted. Yet they would, I am sure, well repay the careful study of any qualified naturalist who would undertake to work them out. Impressions of eye-lenses are very abundant and well preserved. The following names have been provisionally assigned by Peach and others, but there are probably more than nine species represented.

Calymene Sternbergii,
,, Blumenbachii, (?)
Phacops Latreilli,
,, batracheus,
,, latifrons,
,, laciniatus,
,, (trimerocephalus) lævis,
,, (acaste) mimus,
Portlockia.

(*f*) MOLLUSCA.—Brachiopods are very numerous, and many of them have been placed on tablets, numbered, and named with more or less of

accuracy. The Ordovician species include—

Orthis Budleighensis,
,, Calligramma,
,, Scotica,
,, testudinaria, (?)
,, Vespertilio,
Strophomena grandis, etc., etc.

These form a very interesting series, most of which were named by the late Mr. Thomas Davidson, F.R.S.

The Devonian Brachiopods are still more numerous, but will be more advantageously studied when more preliminary work has been done upon them. The following genera seem to be recognizable:—

Spirifera,
Orthis,
Rhynchonella,
Streptorhynchus,
Stringocephalus,
Meganteris,
Centronella,
Atrypa,
Athyris,
Chonetes,
Strophomena,
Productus,
Strophalosia,
Leptœna,
Lingula.

Lamellibranchs, Gasteropods, and Pteropods are somewhat rare, Cephalopods are much more common, but as yet the collections of these are hardly in a condition for successful study and comparison.

Royal Geological Society of Cornwall.

THE EIGHTY-FOURTH

ANNUAL REPORT

ETC., ETC.

PENZANCE
1898.

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Stephen Thomas.

The Secretary requests the favour of his being informed of any inaccuracies in the foregoing lists.

THE

ANNIVERSARY ADDRESS OF THE PRESIDENT,

JOHN DAVIES ENYS, Esq., F.G.S.,

To the General Meeting, November 9th, 1897.

Ladies and Gentlemen,—I have great pleasure in handing to Howard Fox the "Bolitho" Gold Medal for 1897, and in doing so I am glad it has fallen to me as my first act as President of the Royal Geological Society of Cornwall to have that duty to perform.

Mr. Fox contributed to our *Transactions*, with Mr. Alexander Somervail, in 1883, a paper on the "Lizard Rocks," one of the most disputed parts of Cornish Geology.

In later numbers he has contributed interesting papers on a part of the same formation, and by his skilful observations has traced the deposit of Radiolarian Chert from Mullion Island in a long line to the N.E. of that place.

By this discovery he has indicated a definite strata, which will help those who come after him in locating rocks either above or below this formation, or, in other words, has paged one of the leaves of the Cornish book of Geology.

I cannot help adding that Mr. H. Fox carries on the work of his honoured uncle, Robert Were Fox, many of whose papers are valuable features of our *Transactions*, and whose discoveries in the deposit of minerals by electric action have given his name a European reputation.

I am glad to see Miss A. M. Fox* has been able to be present at our meeting.

* Miss Fox died shortly after (November 18th).

A short time since I purchased of the heirs of Edward Opie, of Plymouth, a great-nephew of John Opie, R.A., a copy of an original portrait painted by John Opie in 1805 of Davies Giddy, afterwards better known as Davies Gilbert. This portrait I have pleasure in presenting to the Royal Geological Society, as Mr. Davies Gilbert was our first President, which office he retained till his death in 1839, attending regularly, if possible, the meetings, which were arranged to fall in with his annual visits to Cornwall, Mr. Gilbert often riding the whole way from Eastbourne, in Sussex, no slight undertaking in the days before the Great Western was opened.

I am glad to say that Mr. T. R. Bolitho has offered to present a frame for the picture.

When John Opie, R.A., was painting the original he remarked that Davies Giddy was worth painting and taking trouble over as "he was no fool."

Before accepting the office of President of the Royal Geological Society I pointed out that not being a geologist, though fond of geology, I could not give a geological address on any definite point.

I was told I should not be the first of the kind, so consented to act for want of a better qualified person.

I thought that I could try and show how Cornish Geology was worked out, but was met by the list of 654 papers by 237 writers, many of which were published in *Transactions* to which I had no access without visiting London, so I have put together such notes of work done by this Society in publishing papers, and also made some notes of such geological information as has appeared in our county histories and other works on Cornwall.

First comes Carew's *Survey of Cornwall*, published in the last year of Queen Elizabeth's reign—1602—and I give a few extracts from the first edition, page 6:—

"These mynerals are not so deepe buried by nature in the entrailes of the earth, nor so closely couched amongst the Rocks, but that desire of gaine with the instrument of Art can digge them up: they may bee divided into stones and mettals.

"Quarrie stones are of sundrie sorts, and serve to divers purposes, For walling, there are rough, and *Slate:* the rough maketh speedier building, the *Slate* surer. For Windowes, Domes, and Chimnies, Moore stone carrieth chiefest reckoning. That name is bestowed on it, by the Moores or waste ground, where the same is found in great quantities, either laying upon the ground, or verie little under.

"Pentuan digged out of the Sea Cliffes, and in colour somewhat resembleth gray marble, Caraclouse blacke, not unlike the Jeat, the third taken out of inland Quarries, and not much differing from the Easterne freestone."

He goes on to record the use of three sorts of slate:—

"The first and best blue, the second Sage leafe coloured, the third and meanest Gray." These slates are called Healing-stones.

"The *Slate* is a substance thinne, in colour faire, in waight light, in lasting strong, and generally carrieth so good regard, as (besides the supplie for home provision) great store is yeerely conveied by shipping both to other parts of the Realme, and also beyond the Seas, into Britaine and Netherland."

Mentions Lyme stone. Copper, Silver, Gold, Dyamonds, Pearle, Agates, and white Corall he has been credible informed.

In regard to British Pearles, which were so much valued in ancient Rome, it is a curious fact that the building of bridges over the rivers has been the cause of their becoming much less abundant than formerly. The fording the streams by cattle often damaged the mussels, which in consequence formed pearls; this damage not taking place in the same way now, therefore, is the indirect cause of the decrease of the valuable pearl.

White coral is hardly to be called a Cornish production.

By Dyamonds I have no doubt Carew means the clear spar known as Cornish diamonds even now.

Then comes Tynne. Carew describes the way of working it: finding loads by Dreams and other ways. Carew mentions the supposition that tin groweth. Then follows a long and, for the time, good description of the mode of working the metal.

In regard to tin growing I would point to the fact recorded by

J. H. Collins of stags' horns being found in the stream working of Carnon, with tin deposited in the structure of the horn, as showing the expression is not so far from the truth as it at first appears.

Nordon wrote about the same time, or earlier, than Carew, but his work was not published till 1728. Page 11 :—

"The greatest and chiefeste Jurisdiction and Royaltie belonging unto this *Dukedome* (Cornwall) is that of the *Stannaries.* And greateste profit may be raysed by it unto his *Highnes.*

"Manie thinges ar properlye necessarie to be spoken towchinge the Stannaries, which rayseth a Comoditie moste behoofefull for necessarie use, in domesticall utensells. And therefore no Comoditie (corne and wull excepted) of this kingdome is more vendible, and more spetially regarded in all foraigne partes, Christian and heathen, dearer prized and more valued. In some Countries the fineste golde is not so precious.

"It is a mettall growing for the moste part amonge the hard and infrangable rockes, in the Moares and mountaynes the *owre* thereof being an obdurate stone spred in the veynes of the mountaynes, *wherof* the workes and maner of working is of two sortes, Streame workes and Loade workes. The Streame are in the brookes, in the valleys among the hills. The Loade workes in the mountaynes. The Streame workes are shallowe and more easie: the Loade workes deepe, paynfull and dungerous."

He goes on to record that the earliest pickaxes were of wood, and horn, and such like.* Men worked for 8*d.* a day, or 5 to £6 per annum.

He says that a kind of stone is to be found scattered about which, though hard, is split with wedges in such a manner as to be used instead of timber for posts to hang gates, and to be used for doorways and other purposes.

This is his description of granite.

In 1750 R. Heath published *A Natural and Historical Account of the Isles of Scilly and a General Account of Cornwall.*

* Many of these implements are to be seen at the Museum of the Royal Institution, and in other museums.

In 1778 W. Pryce published his well-known *Mineralogia Cornubiensis*, the first important contribution to the knowledge of the mineral riches of the county.

In 1787 came out the translation of Klaproth's *Mineralogical and Chemical History of the fossils of Cornwall.*

Coming on to a later date, 1797 and 1802, we find that Philip Rashleigh published his work on the *Mineralogie of Cornwall*, with illustrations from specimens still existing at Menabilly.

Many papers in different societies were published about the same time, mostly taking up the mineralogical side of the subject.

W. Smith published his map of England on August 1st, 1815, and the foundation of the present science of Geology dates from that time. The word Geology does not occur in the *Encyclopædia Britannica* of 1800.

The Geological Survey of Cornwall, under Sir Henry de la Beche, is the foundation of the present knowledge of the Geology of Cornwall. De la Beche divided the older formations into different strata. This was much helped by the discovery of fossils, the first record of which I have been able to find is recorded by C. W. Peach in 1836.

C. W. Peach, in his different papers, records the discovery of fish remains and other fossils in widely-scattered places, which have helped much in locating definite lines of divisions. Collins has pointed out that certain lines of divisions can be traced between the so-called Silurian and other formations.

Mr. Howard Fox's discovery of Radiolarians in the Mullion district has thrown a new light on some of the rocks of the Lizard district.

Sir Archibald Geikie's volume on the *Founders of Geology* consists of a series of six lectures delivered at the John Hopkins University, Baltimore, in inauguration of the lectureship founded there in memory of Professor G. H. Williams. In this work he says he determined to discuss the historical development of Geology, confining himself mainly to the latter half of last century and the early decades of this. A period more

fruitful in the progress of Geology it would be impossible to discover. At its beginning the very term Geology was not in existence, and such geological studies as were prosecuted were regarded as a part of mineralogy or physical geography. At its close Geology had established itself as an important and well-defined branch of scientific inquiry, embracing a number of specialized subdivisions. In the interval the great controversy between the Neptunists and the Vulcanists had arisen and practically been settled, Hutton had propounded his theory of the earth, Sir James Hall had introduced the experimental study of geological processes, and stratigraphical observation had been developed into a potent means of attacking the problems of geological chronology.

In 1818 the first volume of the *Transactions* of the Royal Geological Society of Cornwall came out, and I shall take these volumes and run through the papers, or, rather, mention the authors of the papers that have appeared in them. And it is interesting to see how many eminent men have furnished papers to our volumes.

In vol. i. we have the name of Dr. John Ayrton Paris as the author of the first published paper on the subject "The Recent Formation of Sandstone on our North Coast."

Dr. Paris, of course, can only be claimed as Cornish by his residence in Penzance for some time.

The second paper is by Dr. John Davy.

Ashhurst Majendie follows with two papers on "The Scilly Islands" and "The Lizard."

In No. 5 we reach the name of Sir Humphry Davy, who writes "Hints on Geology"—a subject not that by which he made his name so well known, but one with which his chemical studies often brought him into touch.

Paper 6 is by William Gregor, a man who in his day took a forward part in scientific research, but whose works are now mostly forgotten.

No. 7 a Cornish name follows—John Henry Vivian—who writes in connection with "The Copper Industry," with which his name is so intimately associated.

In Nos. 10 and 12 we have Joseph Carne on "The Elvan Courses of Cornwall and the Discovery of Silver in Cornwall"—a name associated with our institution for many years, and whose daughter wrote papers in later volumes.

In No. 11 we have S. J. Trist and the Rev. John Rogers—afterwards Canon of Exeter Cathedral—starting their papers in our *Transactions.*

In No. 13 John Hawkins first appears in the list of persons contributing papers, which run through many volumes.

In No. 18 the well-known name of Henry Boase first appears in connection with the introduction of the steam-engine into Peru, by Richard Trevithick.

I have dwelt on vol. i. as it is the starting-point of the work published by our Society, and I shall not devote the same length of time to the following volumes:—

Vol. ii. is distinguished by the first paper published by this Society by Robert Were Fox, and is on a subject he made his own in a great measure, though others followed him. This subject is "The Temperature of Mines." The conclusions he arrived at are, I believe, generally accepted.

Dr. John Forbes, afterwards known as Sir John Forbes, has a long paper on the same subject.

Mr. H. Boase has a paper on a subject which has been taken up in subsequent numbers by many others in the form of papers on "The Raised Beaches; or, the Submerged Forests." Mr. H. Boase's paper is on "The Submersion of Parts of Mounts Bay and the Inundation of Sandhills."

No. 13 is an interesting paper, communicated by John Hawkins, by Philip Rashleigh, on one of the valleys which run down to Par.

Stream works have long been given up in these valleys, and therefore papers on them cannot be now written from personal observation, and we must be thankful for all the records of them that have been published.

Papers on this subject will be found in 1830 by Canon Rogers, recording roots of trees found when the harbour of Porthleven was built.

1841, Rev. Edward Budge on "The Conglomerate Raised Beaches of the Lizard District."

In 1845 J. Carne wrote on "The Submerged Forest of Mounts Bay."

In 1847 "Diminution of the Mounts Bay Sandhills" is discussed by Richard Edmonds; and a paper by S. R. Pattison on "Post-tertiary Deposits at Bude" is also published.

In 1851 Joseph Carne writes on "Raised Beaches."

In 1865 William Pengelly writes on "Raised Beaches."

In 1883 R. N. Worth has a paper on "A Raised Beach at the Hoe, Plymouth."

A closely allied subject—the stream works of Cornwall—are described by J. Carne, in 1832, in a paper on "Stream Work at Drift Moor up the Valley above Newlyn, near Penzance," in which is a most interesting account of a wooden waterwheel and chain pump found buried in the old works.

In 1847 Sir Charles Lemon has a paper giving an account of a tree deeply buried near Helligan.

R. Q. Couch records the finding of deers' horns in stream works near St. Austell and other places in 1851. A fine and perfect head is preserved at Penrose by Captain Rogers, found near St. Blazey.

The Royal Institution of Cornwall has a good specimen from the Carnon Works.

R. Q. Couch has two more papers on "Alluvial Deposits" in 1855.

In 1860 John Jope Rogers has recorded the strata which form the valley of the Cober between Helston and the Loe Pool.

In 1881 J. H. Collins also writes on "The Finds of Deers' Horns in Stream Works," showing the infiltration of tin into their structure.

In 1829 John W. Colenso writes on "The Pentuan Stream Works," and records oyster shells still adhering to the stone.

M. J. Henwood sums up the evidence to date on the subject.

That Cornwall has at some past time been subject to changes of elevation cannot be doubted, as the evidence of tree-roots still in the positions in which they grew are to be found in

Mounts Bay, Porthleven, Mainpool, and many other places on both south and north coasts.

I should wish that we had evidence of the depth below high tide that tree stumps in position can be traced.

In vol. vii., 1849, this Society has the honour of having published the first paper that appeared by William Pengelly, as is shown by the list of his works published in his life.

In 1830–31 we have the first account of the Geology of Cornwall as a whole. This paper is by Henry Boase, and with it is a map of the county, showing his proposed classification of the formations.

Mr. Boase added short geological notes to Davies Gilbert's publication of the MS. of Hals and Tonkin, which came out in 1838 under each parish, adding much value to the book.

In 1841 Charles William Peach sends a paper on "Fossil Organic Remains," and points out that in 1836 he first records his discoveries of them. Numerous papers from C. W. Peach are published in 1844; in 1845, fixing some of the fossils as of the Silurian age; in 1845 came out two papers.

In 1846 he again publishes another, and in this year Sir Roderick T. Murchison, in an interesting paper, definitely accepts the Silurian as the age of some of Mr. Peach's finds of fossils.

R. Q. Couch also describes fossiliferous rocks at the same date.

Mr. Peach again writes in 1847 two papers.

In 1849 John Giles, of Liscard, sends a paper on the fossils of that neighbourhood.

Mr. Peach also follows up his subject, and is joined by Mr. Pengelly with his paper on "Fish Remains."

S. R. Pattison takes up the vegetable as against the animal forms of life in Cornish strata.

The same year Mr. Peach describes the fossils from the Blackhead, near St. Austell.

And Mr. S. R. Pattison describes the fossil beds at Petherwyn, and gives a long list of fossils.

In 1855 C. W. Peach sends the first of his papers on

"Caithness and Ross-shire," and in one claims justly the credit of being the first to collect Silurian fossils in the West, namely, in Cornwall and in the north of Scotland, in Ross-shire.

In the same year we have a paper by Jonathan Couch on "Fossils from near Trelawny," also one on "Silurian Fossils" from R. Q. Couch.

W. Pengelly again sends a paper on "Devonian Fossils" in 1859.

Mr. Peach again writes on fossils in 1881 in two papers.

Mr. C. W. Peach's types are preserved in our museum; and Mr. R. Etheredge, when on a visit to receive the first Bolitho Medal, pointed out the great value of these collections to geological science.

In 1846 S. R. Pattison describes "The Carboniferous System of the North-East, or Bude District," and distinguishes it from the older formation of the greater part of Cornwall.

In 1847 he again came forward with an account of the neighbouring district of Tintagel, followed by R. Q. Couch on the then knowledge of Geology in the county; he also has a paper on a small Devonian formation near Launceston.

In this year, 1847, John Garby gives a long, and I think interesting, catalogue of the minerals found in Cornwall.

In the volume for 1860 one of our late Presidents, Sir Warrington Smyth, describes the great Perran iron lode, and in 1882 publishes a paper on the Duchy Peru Lode in the same place.

Of the great work published in our volumes by W. J. Henwood, I need not say much, as they stand on their own merit, and will remain for ever as a monument of elaborate research, much of which cannot be repeated, as so many of the mines are closed.

In 1860 Augustus Smith draws attention to the occurrence of chalk flints on the Isles of Scilly. I have seen them there, and also on the headlands in the Land's End district. Personally these flints are a great puzzle, as the nearest are in Dorsetshire. Human agency seems the most probable explanation.

I shall spare you going through all the other papers, and come on to one of the most interesting discoveries of modern times.

I mean the beds found near St. Erth Churchtown, which have been recently re-examined by Alfred Bell.

Some time since Robert Etheredge suggested that more ought to be known in regard to this deposit, which practically stands alone in Great Britain, and indeed in the whole of Northern and Central Europe.

That a formation should exist in Cornwall which has shells and other remains the nearest allies of which are in the Straits of Messina, is enough to give great interest to their exploration.

Mr. Etheredge, in conjunction with the writer, sent out proposals, and having met with sufficient encouragement, Mr. Alfred Bell came down to examine the St. Erth beds. I met Mr. Bell, and called on Mr. Harvey at Hayle, and afterwards on the Rev. C. R. D. Carter at St. Erth Vicarage, and we were very kindly received by both, and full leave given to investigate the pits in which the sand is dug, and in the Vicarage pits the fossiliferous clays are reached.

Mr. Bell has sent a full paper on his researches, and as this will be put before you during this meeting I shall not attempt to forestall what results he has arrived at.

A full set of specimens will be deposited in our museum for future reference.

Of the classical works of Sir H. Thomas de la Beche, published as Part I. of the volumes of *The Geological Survey of S.W. of England*, I can say (even my slight knowledge of Geology enables me to do so) that no paper has stood the test of time better than his.

Men reasoning from small areas have at times tried to upset his statement, which had been arrived at with the knowledge of the whole district of the West of England, and in most cases Sir H. T. de la Beche's conclusions have been borne out in their general scope.

Sir Henry T. de la Beche published papers in our *Transactions* while engaged in the survey of Cornwall.

The Rev. Adam Sedgwick's and Sir Roderick T. Murchison's papers on the classification of the older rocks of Devon and Cornwall ought to be mentioned.

In this sketch of work done by this Society in publishing in their earlier volumes the works of real value, I have passed over many papers on local subjects of interest, and have hardly mentioned the work on mines and mineralogical subjects, not that I undervalue those papers.

Mr. C. Twyte, at the combined meeting of the Cornish Society held at Falmouth in 1896, proposed that the Government should be asked to re-survey Cornwall geologically, as this county was one of the first undertaken, and that the published maps were not up to date.

A memorial was prepared, and thanks to the help received from Lord Mount Edgcumbe, our Cornish members, and others, the Government have undertaken the work, and Mr. J. Bastian Hill has already started the work.

In concluding these few disjointed remarks, I fear I have fully justified the statement I started with, that I was not more than an amateur in Geology.

REPORT OF THE COUNCIL.

At the Annual Joint Meeting of the Scientific Societies of Cornwall at Falmouth, in August, 1896, it was resolved that application should be made to the Government for a new geological survey of the county. The details were ultimately left in the hands of the officers of this Society, and in their last Report your Council expressed their approval of and hearty co-operation in the proposal. The application was duly made, and we are now pleased to be able to report that the survey has been authorized and the work actually commenced. Mr. J. B. Hill, of H.M. Geological Survey, who has been appointed to carry out the work, was unfortunately delayed by ill-health from making a thorough beginning until the autumn. He is now engaged on an exhaustive examination of the sections along the south coast, preparatory to mapping the interior, where good sections are so rare. Mr. Hill has kindly expressed his willingness to lay before the Society all the interesting results of his work. The Council believe it is generally recognized that every effort should be made to ensure the successful completion of an undertaking which combines both scientific and commercial matters of such importance to the county, and they take this opportunity of expressing the hope that all who are interested in the subject, and especially the members of this Society, will be ready to afford him all the assistance which lies in their power, and that many volunteers will be found to help him in the different localities as he gets on with his work. The study of the geology of the county is far from being exhausted, and although the mining is unfortunately stagnant in so many parts, phenomena of interest are still being daily brought to light. The

opportunity of practical search and discovery which the visit of a skilled working geologist in every corner of the county affords ought to stimulate the popular interest, and encourage a number of students.

During the year, through the efforts of Mr. J. D. Enys, Mr. H. Fox, and others, a complete examination has been made of the pliocene beds at St. Erth by Mr. A. Bell, F.G.S. Mr. Bell was engaged in actual research in the clay-pits for several weeks in August and September, and the paper which he contributes to our proceedings to-day is the authentic and complete account up to date of this famous and interesting discovery.

At the Annual Joint Meeting of the Cornish Scientific Societies this year the question of preserving the plans and sections of the abandoned mines was brought forward. When a mine is closed the plans in many cases pass into private hands, and the changes caused by deaths and removals render them liable to loss and destruction. Should the much hoped for revival in Cornish mining occur, and the hope is certainly not abandoned, many of the old mines will be re-opened, and these plans and sections will then become of great importance, and great difficulty will be experienced in finding them unless some steps have been taken for their preservation. Their preservation can be best ensured if they are placed in the libraries and museums of the permanent institutions, and this Society will be very pleased to accept the custody of any such documents which may be entrusted to them. A list of all which were in this building could be kept, and the original would then be always available and safe from the risks to which they are now subject.

The Council have decided to award the William Bolitho gold medal for this year to Mr. Howard Fox, F.G.S., feeling confident that his scientific abilities and the cordial interest which he has taken in the welfare of the Society will win your thorough approval of the decision.

The Council has much pleasure in recommending the election of Mr. J. H. Collins as an honorary member as a slight

acknowledgment of the many and great services which he has rendered to the Society.

It will be interesting to the members to know that the interchange of publications with so many scientific societies, which gives the great value to the Library of this Society, continues without abatement, and the Library has been further enriched during the year by a copy of *British Palæozoic Fossils*, presented by the author, Professor R. Etheridge, F.R.S., F.G.S.; and by the *Life of William Pengelly*, presented by the publishers, Messrs. Murray.

The Council regret to record the loss of Major-General G. B. Tremenheere, an honorary member, and the resignation of Major J. J. Ross, who has held the office of Librarian for many years.

LIBRARIAN'S REPORT

From November 1st, 1896, to October 31st, 1897.

THE following works have been added to the Library during the year:—

I. TRANSACTIONS, JOURNALS, AND REPORTS.

Presented by the respective Societies, Editors, and other Donors, or Purchased.

Adelaide. South Australian School of Mines and Industries, and Technological Museum.

Eighth Annual Report, 1896. 8vo. Adelaide, 1897.

Boston. American Academy of Arts and Sciences.

Proceedings: New Series, vol. xxiii., May, 1895, to May, 1896. Including Index. Roy. 8vo. Boston, 1896.

Proceedings: Vol. xxxii., Nos. 1–15, November, 1896, to May, 1897. Roy. 8vo. Boston, 1896–1897.

Cambridge. Library Syndicate.

Forty-third Annual Report for the year ending December 31st, 1896. 4to. Cambridge, 1897.

Canada. Canadian Institute, Toronto.

Transactions: Vol. v., part 1, October, 1896.
Roy. 8vo. Toronto, 1896.

Proceedings: Vol. i., part 1, No. 1, February, 1897.
Roy. 8vo. Toronto, 1897.

——. Geological Survey of Canada.

Annual Report for the year 1894.
New Series, vol. vii., with maps.
Roy. 8vo., cloth. Ottawa, 1896.

Canada. Geological Survey of Canada.
Annual Report for the year 1895.
New Series, vol. viii., with maps.
Roy. 8vo., cloth. Ottawa, 1897.

Natural History Society of Montreal.
The Canadian Record of Science, including the Proceedings of the Society, vol. vii., Nos. 1–4.
8vo. Montreal, 1896–1897.

Chicago. Academy of Sciences.
Thirty-ninth Annual Report for the year 1896.
8vo. Chicago, 1897.

Geological and Natural History Survey. Bulletin. No. 1.
8vo. Chicago, 1896.

Cincinnati. Society of Natural History.
Journal: Vol. xix., Nos. 1 and 2, August, 1896, to March, 1897. 8vo. Cincinnati, 1896–1897.

Colorado. The Colorado College Scientific Society.
College Studies: Vol. vi., Papers read before the Society.
8vo. Colorado Springs, Colo., 1896.

——. Scientific Society.
Proceedings (in separate pamphlets) viz. :—
The Technical Determination of Iron. By L. J. W. Jones. Read February 3rd, 1896.
Notes on the Occurrence of a rich Silver and Gold Mineral containing Tellurium in the Griffith Lode, near Georgetown, Clear Creek County, Colorado.
Notes on the Occurrence of Tellurium in an Oxidized form in Montana. By Dr. Richard Pearce. Read October 5th and November 2nd, 1896.
An Automatic Water Recording Gauge. By Ernest Le Neve Foster. Read December 7th, 1896.
The Nature of the Chemical Elements (Eighth Paper). Argon and Helium in the Periodic Sequence. By Charles Skeele Palmer, Ph.D. Read January 4th, 1897.

Colorado. Scientific Society.

Magnetic Concentration applied to Sulphide Ore. By G. M. Gouyard. Read February 1st, 1897.

A Recent Assay Balance. By L. S. Austin, Ph.B. Read April 3rd, 1897.

The Oscuro Mountain Meteorite. By R. C. Hills. Read April 3rd, 1897.

Ferric Sulphate in Mine Waters, and its Action on Metals. By L. J. W. Jones. Read June 5th, 1897.

8vo. Denver, 1896–1897.

Dorpat. Dorpater Naturforscher—Gesellschaft.

Sitzungsberichte: Band xi., heft 2, 1896.

8vo. Dorpat, 1896.

Archiv für die Naturkunde Liv, Ehst-und Kurlands. Serie ii., band xi., lief 2, 1896. Roy. 8vo. Dorpat, 1897.

Falmouth. Royal Cornwall Polytechnic Society.

Sixty-Fourth Annual Report. 8vo. Falmouth, 1896.

Freiberg. Jahrbuch für das Berg-und Hüttenwesen im Konigreiche Sachsen auf das Jahr, 1896. 8vo. Freiberg, 1896.

Glasgow. Geological Society.

Transactions: Vol. x., part 2, 1894–96.

8vo. Glasgow, 1896.

[Including Index and Title-page of vol. x.]

Havre. Société Géologique de Normandie.

Bulletin: Tome xvi. Années. 1892–93.

Roy. 8vo. Havre, 1894.

India. Geological Survey of India.

Memoirs: Vols. xxv. and xxvi.

Roy. 8vo. Calcutta, 1895–1896.

,, Palæontologia Indica: Series xvi., vol. i., part 1.

4to. Calcutta, 1895.

Records: Vol. xxix., part 4, 1896.

,, Vol. xxx., parts 1–3, 1897.

Roy. 8vo. Calcutta, 1896–1897.

Indiana. Academy of Science.
Proceedings: 1894–1895.
Roy. 8vo. Indianapolis, 1895–1896.

Iowa. Geological Survey.
Fourth Annual Report, vol. v., 1895.
4to. Des Moines, Iowa, 1896.

Kansas. Academy of Science.
Transactions of the Twenty-sixth and Twenty-seventh Annual Meetings, 1893–1894, vol. xiv.
Roy. 8vo., cloth. Topeka, Kansas, 1896.
A Brief History of the Organization, with Constitution, By-Laws, and Membership. 8vo. Kansas, 1897.

Leicestershire. Literary and Philosophical Society.
Transactions: Vol. iv., part 6, October, 1896.
„ „ „ 7, January, 1897.
„ „ „ 8, April, 1897.
„ „ „ 9, July, 1897.
8vo. Leicester, 1896–1897.

Liverpool. Engineering Society.
Transactions: Vol. xviii., Session xxiii.
8vo. Liverpool, 1897.

——. Literary and Philosophical Society.
Proceedings: No. 50, Session 85, 1895–96. Including Index to Papers contained in vols. i.–l., 1844–1896.
No. 51, Session 86, 1896–1897.
8vo., cloth. Liverpool, 1896–1897.

London. Geological Survey.
Annual Report for year ending 31st December, 1895.

——. Geological Society of London.
Quarterly Journal:
Vol. lii., part 4, No. 208, November, 1896. Including Index and Title-page to vol. lii.

London. Geological Society of London.

Vol. liii., part 1, No. 209, February, 1897.

„ „ 2 „ 210, May, 1897.

„ „ 3 „ 211, August, 1897.

8vo. London, 1896–1897.

Index to vols. i.–l., part 1, No. 200A.

„ „ „ 2 „ 200B.

8vo. London, 1897.

Catalogue of Geological Literature added to the Society's Library during the year ended December 31st, 1896.

8vo. London, 1897.

Abstract of Proceedings, Session 1896–97.

——. Geologists' Association.

Proceedings: Vol. xiv., part 10, November, 1896. Including Index, Title-page, and Contents Table of vol. xiv.

Vol. xv., parts 1–4, March to August, 1897.

8vo. London, 1896–97.

——. London, Edinburgh, and Dublin Philosophical Magazine.

Series v., vol. xlii., Nos. 258 and 259, November and December, 1896. Including Index and Title-page, and Contents of vol. xlii.

Series v., vol. xliii., Nos. 260–265, January–June, 1897. Including Index and Title-page, and Contents of vol. xliii.

Series v., vol. xliv., Nos. 266–269, July–October, 1897.

8vo. London, 1896–1897. *Purchased.*

——. Mines and Quarries.

Summaries of Statistics relating to the Mines and Quarries in the United Kingdom and the Isle of Man, obtained by Her Majesty's Inspectors of Mines. Also List of Inspectors and Inspection Districts.

Folio. London, 1897.

London. Mines and Quarries.

List of the Plans of Abandoned Mines deposited in the Home Office, including Plans transferred from the late *Mining Record Office*, corrected to the 31st December, 1896. 4to. London, 1897.

Reports of C. Le Neve Foster, Esq., H.M. Inspector of Mines for the North Wales, etc., District (No. 9) for the year 1896. Folio. London, 1897.

List of Quarries (under the Quarries Act) in the United Kingdom of Great Britain and Ireland and the Isle of Man, year 1895. Prepared by H.M. Inspector of Mines. Folio. London, 1896.

[Presented by C. Le Neve Foster, Esq.]

——. Palæontographical Society.

Vol. l. for 1896. 4to. London, 1896. *Purchased.*

——. Royal Society.

Proceedings:

Vol. lx., Nos. 362–364, November–December, 1896.

„ „ 365–367, February–March, 1897.

Vol. lxi., Nos. 368–378, March–August, 1897.

Vol. lxii., Nos. 379–380, September–October, 1897.

Index, Title-pages, and Tables of Contents of vols. lx. and lxi. 8vo. London, 1896–1897.

Manchester. Geological Society.

Transactions:

Vol. xxiv., part 10, Session 1895–1896.

Vol. xxv., parts 1–11, Session 1896–1897.

Index and Title-pages for vols. xxiii. and xxiv. 8vo. Manchester, 1896–1897.

——. Geographical Society.

Journal: Vol. xii., Nos. 1–9, January–September, 1896. 8vo. Manchester, 1896–1897.

Minnesota. Academy of Natural Sciences.
Bulletin: Vol. iv., part 1. 8vo. Minneapolis, 1896.

Netherlands—India. Jaarboek van het Mijnwezen in Nederlandsch Oost-Indië Uitgegeven op last van Zijne Excellentie, den Minister Van Koloniën. 25th year, 1896. Technisch-Administratief-en-Wetenschappelijk Eerste Gedeelte.

25th year, 1896. Technish-en-Administratief Tweede Gedeelte.

26th year, 1897. Technisch-Administratief-en-Wetenschappelijk Gedeelte. 8vo. Amsterdam, 1896–1897.

——. Atlas, containing Six Maps.
Oblong 4to. Amsterdam, 1897.

Newcastle-upon-Tyne. North of England Institute of Mining and Mechanical Engineers.

Transactions: Vol. xlv., part 4, issued August, 1896.
„ „ „ 5, issued November, 1896.
(Including Title-page and Table of Contents of vol. xlv.)

Transactions: Vol. xlvi., part 1, issued December, 1896.
„ „ „ 2, issued February, 1897.
„ „ „ 3, issued April, 1897.
Royal 8vo. Newcastle-upon-Tyne, 1896–1897.

Annual Report for the year 1896–1897.
Royal 8vo. Newcastle-upon-Tyne, 1897.

New South Wales. Department of Mines and Agriculture.
Australian Mining Standard, vol. xii.

The Silver Sulphides of Broken Hill (Special Edition).
4to. Sydney, N.S.W., 1896–1897.

Records of the Geological Survey, vol. v., part 2.
4to. Sydney, N.S.W., 1897.

New South Wales. Royal Society of New South Wales.
Journal and Proceedings: Vol. xxix., 1895.
" " " xxx., 1896.
8vo. Sydney, N.S.W., 1895–1897.

New York. American Geographical Society.
Bulletin: Vol. xxviii., Nos. 3 and 4, 1896. Including Index for vol. xxviii.
Bulletin: Vol. xxix., Nos. 1 and 2, 1897.
8vo. New York, 1896–1897.

——. American Museum of Natural History.
Bulletin: Vol. viii., 1896. Including Index to vol. viii.
Royal 8vo. New York, 1896.
Annual Report for the year 1896.
8vo. New York, 1896.

——. Academy of Sciences (late Lyceum of Natural History).
Transactions: Vol. xv., October, 1895, to June, 1896. Including Index to vols. i.–xv. inclusive.
Roy. 8vo. New York, 1896.
Annals: Vol. ix., Nos. 4 and 5, January, 1897.
8vo. New York, 1897.

North Carolina. Elisha Mitchell Scientific Society.
Journal: vol. xiii., parts 1 and 2, January–December, 1896.
8vo. Raleigh, N.C., 1897.

Nova Scotia. Nova Scotian Institute of Science.
Proceedings and Transactions (Second Series): Vol. ix., part 2, Session 1895–1896. 8vo. Halifax, N.S., 1896.

Paris. École des Mines.
Annales des Mines: Série ix., tome x., liv. 10–12, de 1896.
Table des Matieres: du tome v., Série ix., tome xi., liv. 3 and 4, de 1897. 8vo. Paris, 1896–1897.

Philadelphia. Academy of Natural Sciences.

Proceedings: Parts 2 and 3, April–December, 1896. Including Index and Title-page to vol. for 1896.

Proceedings: Part 1, January–March, 1897.
Roy. 8vo. Philadelphia, 1896–1897.

——. American Philosophical Society.

Proceedings: Vol. xxxv., Nos. 151–152, August–November, 1896.

Proceedings: Vol. xxxvi., No. 154, January, 1897.
8vo. Philadelphia, 1896–1897.

Transactions: Vol. xix. (New Series), part 1. Article 1: "A New Method of determining the General Perturbations of the Minor Planets," by William McKnight Ritter, M.A. Article 2: "An Essay on the Development of the Mouth Parts of certain Insects," by John B. Smith, Sc.D. 4to. Philadelphia, 1896.

Pisa. Società Toscana di Scienze Naturali.

Processi Verbali: Vol. x., pages 121–241, August, 1896, to May, 1897. Roy. 8vo. Pisa, 1896–1897.

Memorie: Vol. xv. Roy. 8vo. Pisa, 1897.

Queensland. Queensland Museum.

Annals: No. 3. 8vo. Brisbane, 1897.

Sweden. Geological Institution (University of Upsala).

Bulletin: Vol. ii., part 2, No. 4. 1894–1895.
Roy. 8vo. Upsala, 1896.

United States. Department of the Interior. Geological Survey.

Sixteenth Annual Report, 1894–1895. By Charles D. Walcott, Director. Part 1 containing Report of the Director and Papers of a Theoretic Nature: "The Dinosaurs of North America," by O. C. Marsh; "Glacier Bay and its Glaciers," by H. F. Reid; "Some Analogies in the Lower Cretaceous of Europe and America," by

L. F. Ward; "Structural Details in the Green Mountain Region and in Eastern New York," by T. Nelson Dale; "Principles of pre-Cambrian North American Geology," by C. R. van Hise; "Flow and Fracture of Rocks as Related to Structure," by Leander Miller Hoskins; "Summary of Primary Triangulation executed between the years 1882 and 1894," by Henry Gannet.

4to, cloth. Washington, 1896.

Seventeenth Annual Report, 1895–1896. By C. D. Walcott, Director. Part 3. Mineral Resources of the United States, 1895. Metallic Products and Coal. "Iron Ores," by John Birkinbine; "Present Condition of the Iron and Steel Industries of the United States," by James M. Swank; "Copper," "Lead," and "Zinc," by Charles Kirchkoff; "Manganese," by Joseph D. Weeks; "Chromic Iron, with Reference to its Occurrence in Canada," by William Glenn; "Antimony and Coal," by Edward W. Parker. Part 3 continued. Non-Metallic Products except Coal. "Coke," "Petroleum," and "Natural Gas," by Joseph D. Weeks; "Asphaltum," by Edward W. Parker; "Stone," by William C. Day; "Soapstone," by Edward W. Parker; "Statistics of the Clay-working Industries of the United States in 1895," by Jefferson Middleton; "The Pottery Industry of the United States," by Heinrich Ries; "Portland Cement," by Spencer B. Newberry; "American Rock Cement," by Uriah Cummings; "Precious Stones," by George F. Kunz; "Abrasive Materials," by Edward W. Parker; "Sulphur," "Pyrites," "Gypsum," "Salt," "Asbestos," "Mineral Paints," "Barytes," by Edward W. Parker; "Mineral Waters," by Albert C. Peale.

4to, cloth. Washington, 1896.

Victoria. Geological Society of Australasia.

President's Inaugural Address, 25th September, 1896. Session 1896. 8vo. Melbourne.

Vienna. K.K. Geologischen Reichsanstalt.

Verhandlungen: Nos. 10 18, 1896. Including Title-page and Index for vol. Roy. 8vo. Wien, 1896.

Verhandlungen: Nos. 1–10, 1897. Roy. 8vo. Wien, 1897.

Washington. Smithsonian Institution.

Annual Report of the Board of Regents to July, 1894.

" " " " " 1895. Roy. 8vo, cloth. Washington, 1896.

Annual Report of the U.S. National Museum to June 30th, 1893.

Annual Report of the U.S. National Museum to June 30th, 1894. Roy. 8vo., cloth. Washington, 1895–1896.

Western Australia. Geological Survey.

General Annual Report for 1888–1889. By Harry Page Woodward, Government Geologist. 8vo. Perth, W.A., 1890.

Report on the Goldfields of the Kimberley District, 1891. By Harry Page Woodward. 8vo. Perth, W.A., 1891.

The Goldfields Act, 1895, with Regulations for the Management of the Goldfields of the Colony. 8vo. Perth, W.A., 1896.

Mining Handbook to the Colony of Western Australia, 1894.

Mining Handbook to the Colony of Western Australia, 1895 (Second Edition). By Harry Page Woodward. 8vo. Perth, W.A., 1894–1895.

Ad Interim Report on the Department of Mines for half-year ending June 30th, 1894. Roy. 8vo. Perth, W.A., 1894.

Report on the Department of Mines for the years 1894–1895, with Supplementary Notes on part of 1896. Roy. 8vo. Perth, W.A., 1895–1896.

Geological Notes on the Coolgardie Goldfields. By Dr. Charles Chewings, Ph.D., F.G.S.

A Paper read before the Royal Colonial Institute, March 17th, 1896. 8vo. Perth, W.A., 1896.

II. GEOLOGICAL AND MISCELLANEOUS PUBLICATIONS.

Presented by the Authors or other Donors.

Etheridge, R. Fossils of the British Islands. Vol. i. Palæozoic. By Robert Etheridge, F.R.S., L. & E., F.G.S., etc. 4to. Oxford, 1888.
[Presented by the Author.]

Hinde, G. J. Supplementary Notes on the Radiolarian Rocks in the Lower Culm-Measures to the West of Dartmoor. By George J. Hinde, Ph.D., and Howard Fox, F.G.S. [Read at Ashburton, July, 1896.] 8vo.
[Presented by the Authors.]

Holland, T. H. Report on the Geological Structure and Stability of the Hill Slopes around Naini Tal. Including Geological Map of Naini Tal. By T. H. Holland, A.R.C.S., F.G.S. Roy. 8vo. Calcutta, 1897.

On some Norite and Associated Basic Dykes and Lava-Flows in Southern India. By Thomas H. Holland, A.R.C.S., F.G.S. Roy. 8vo. Calcutta, 1897.

An Account of the Geological Specimens collected by the Afghan-Baluch Boundary Commission of 1896. With Plate. By Thomas H. Holland, A.R.C.S., F.G.S.

Note on an Igneous Dyke and Additional Note on Olivine Niorite Dykes at Coonoor Nilgiri Hills. With Plates. By Thomas H. Holland, A.R.C.S., F.G.S.

On Augite Diorites and Micropegmatite in Southern India. By Thomas H. Holland, A.R.C.S., F.G.S.
[Presented by the Author.]

Symons, B. A Geological Sketch of the Coolgardie Goldfields. By Brenton Symons, F.C.S., M.I.C.E. Demy 8vo. London, 1896.
[Presented by the Author.]

Pengelly. A Memoir of William Pengelly, F.R.S. John Murray. London, 1897.
[Presented by the Publishers.]

Daubrée. Obituary Notice and List of Works of Auguste Daubrée.
[Presented by his Family.]

CURATOR'S REPORT.

Photograph of Mr. G. B. Millet. Portrait of Davies Gilbert, Esq., F.R.S.	J. D. Enys, Esq.
Specimen Slates from Penryn Creek to illustrate paper, vol. xii., part 2.	F. J. Stephens, Esq.
Cinnabar from Redington Mine, California (2 specimens). Bell Metal Ore, Pendeen Mine (3 specimens).	W. Eddy, Esq.
Clays, St. Erth pits. Shells „ „	A. Bell, Esq.
Eight Trilobites, Carnarvonshire.	F. J. Stephens, Esq.
Flint containing a solid. „ „ fossil sponge.	H. Fox, Esq.

TREASURER'S STATEMENT, 1896-97.

Dr. *The Treasurer in Account with the Royal Geological Society of Cornwall.* **Cr.**

November 9th, 1897—	£	s.	d.
To Ordinary Subscriptions and Arrears	54	12	0
„ Donation per H.R.H. The Prince of Wales ...	20	0	0
„ One Year's Dividend on £1500 Midland Railway 3% Stock, less tax	43	10	0
„ Balance	16	14	11
	£134	16	11

November 10th, 1896—	£	s.	d.
By Balance due to Treasurer	5	2	10
November 9th, 1897—			
By Rates and Taxes	0	13	1
„ Housekeeper's Salary	20	0	0
„ Curator, One Year	50	0	0
„ Late Curator, Quarter Year	12	10	0
„ Fire Insurance Premium	2	12	9
„ Books, Binding, &c.	24	19	4
„ Coals, Gas, &c.	9	14	2
„ Repairs to Buildings	4	9	5
„ Sundries	4	15	4
	£134	16	11
„ By Balance due to Treasurer	16	14	11

T. ROBINS BOLITHO, *Treasurer.*

PENZANCE.

LIST OF

PAPERS READ AT THE ANNUAL MEETING,

November 9th, 1897.

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1. Address by Howard Fox, F.G.S., on receipt of the William Bolitho medal.

2. On the Pliocene Shell-Beds at St. Erth. By Alfred Bell, F.G.S.

3. On the Probable Causes of the Absence of Palæolithic Man from Cornwall. By Alexander Somervail.

4. Additions to the List of Foraminifera from St. Erth. By F. W. Millett.

5. On the Geology of the Gold-bearing Regions of North-West Canada. By F. J. Stephens.

6. On a Flint Nodule Containing Liquid. By Howard Fox, F.G.S.

7. The Veryan Limestones. By Howard Fox, F.G.S.

ADDRESS BY HOWARD FOX, F.G.S.,

ON RECEIPT OF THE "WILLIAM BOLITHO" MEDAL.

(Read November 9th, 1897.)

MR. PRESIDENT, LADIES AND GENTLEMEN,—

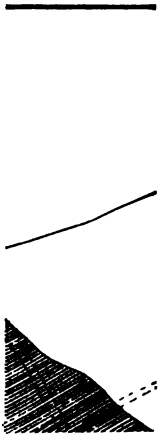
I thank the Council for the high honour they have conferred upon me, and you, Mr. President, for the all too flattering terms in which you have referred to my labours.

It is very gratifying to me to receive the Bolitho medal, not only as a proof that the Council value such geological work as I have been able to do, but also because I had the privilege of being a colleague of the generous founder during a few of the thirty-five long years of his official connection with this Society.

Whatever small service I may have rendered by bringing to light some new facts touching the field geology of our county I owe to three causes. (1) To the companionship and stimulus of my friend Mr. Alexander Somervail, who brought the enthusiasm, the energy, and the knowledge which he acquired in studying his native Scottish rocks, to bear on our Cornish exposures when he migrated from his northern home and fortunately settled at Falmouth. Our tramps round the Lizard,

with tracings of the twenty-five-inch parish maps and Prof. Bonney's Papers on that district in our pockets, are among the most delightful experiences of my life. To Mr. Ussher, of the Geological Survey, I am also deeply indebted for valuable guidance in East Cornwall and elsewhere. (2) To the assistance and co-operation most readily given me by several of the leaders of geological science in London. The time and trouble thus generously and freely accorded by them to tyros is a sacrifice on their part, as far as I am aware, without parallel in any other science or profession. (3) To the fact that Cornwall has not been officially surveyed for some sixty years, and that when the survey was made the microscope had not been applied to the determination of the composition of rocks.

If anything can enhance the gratification of this occasion it consists in receiving this medal at the hands of a grandson of Mr. Davies Gilbert, the first President of this Society and one of the two Cornish Presidents of the Royal Society: at the hands of one who in his encyclopedic knowledge of our county, and in his patriotic support of its scientific institutions, is a worthy representative of his illustrious ancestor.



ON THE PLIOCENE SHELL-BEDS AT ST. ERTH.

By Alfred Bell.

(Read November 9th, 1897.)

Except to the sand-diggers the existence of a bed of shelly clay in the west of Cornwall was unknown, and considerable interest was excited in the scientific world when Mr. N. Whitley, in a paper "On the Evidence of Glacial Action in Cornwall and Devon," referred to a "large bed of pure tough grey clay . . . interstratified between beds of fine siliceous sand," and exhibited several species of shells obtained by him on the spot.[1]

Shortly before the publication of this notice Mr. T. Cornish exhibited a few of the shells both at the Falmouth Jubilee Meeting of the Polytechnic Institution and at Penzance,[2] and at the suggestion of Mr. F. W. Harmer, F.G.S., of Norwich, forwarded to Mr. S. V. Wood, F.G.S. (both interested in tertiary geology), such specimens as he possessed. Mr. Wood being then a confirmed invalid sent them on to my brother, R. G. Bell, for examination, and to show them to Dr. J. Gwyn-Jeffreys, both being familiar with recent and later tertiary shells.

[1] *Trans. R. G. S. Corn.*, on p. 138, 1882. (Read Nov. 4, 1881.)
[2] *Trans. N. Hist. and Ant. Soc.*, 1 N.S., 288, Nov. 17, 1882.

The shells and the clay were so ***unlike*** anything hitherto known in England, and so ***like*** the species and matrix of the South European pliocene deposits, and so much incredulity was displayed as to the "nativeness" of the shells, that Mr. Cornish sent to Mr. Wood a large quantity of the clay for him to look over; and thus satisfied, at his instance fresh excavations were made in the presence of Prof. Warington Smyth and other gentlemen mostly residing in the county, August, 1884.

Meanwhile a few of the more conspicuous examples were saved by the Rev. A. W. Mills, the Vicar of St. Erth, on whose glebe land the pits were situated; by Mr. Goodman, one of the churchwardens; and others, especially by Mr. F. W. Millett, who examined the clay for foraminifera and other microzoa, with the marvellous results communicated to the Society from time to time (*vide Trans.*, vols. x., xi., xii., 1885–1896.

With the help of Mr. Cornish, who was greatly interested in the matter, both in forwarding clay, specimens, and introductions, Mr. S. Wood obtained materials for his paper "On a New Pliocene Deposit at St. Erth,[1] Cornwall," the stratigraphical details obtained from the note-books of Mr. Whitley, and the fossiliferous portion from his own examination of the clays and shells sent him by Messrs. Whitley,

[1] *Proc. Geol. Soc.*, Lond., Feb., 1885, xli. pp. 65–73. (Read Nov. 5, 1884.)

Cornish, Rev. A. W. Mills, Goodman, Millet, and Prof. W. W. Smyth.

Between the reading and the publication of this important paper the author had passed away,[1] and the work of deciphering the mollusca fell to my brother, who had been in communication with Dr. Gwyn-Jeffreys about them.[2]

Mr. Wood had sent a paper embodying the chief points of the above to the Penzance N. H. & A. Soc., unfortunately crowded out for want of time to read; but a short essay in a local newspaper, "The Land's End District from Marazion to Hayle once an Island," contains the most salient features of the memoir, a short reference to the clay being made by Prof. W. W. Smyth at the annual meeting, 1884–5, in his yearly address. (*71st Report*, Nov. 4, 1884, ccxxii.)

In 1885 Mr. Henry Keeping collected largely for the Woodwardian Museum, Cambridge, and Mr. Clement Reid examined the ground on behalf of the Geological Survey of Great Britain; and later in the year Messrs. P. F. Kendall and R. Bell opened a fresh section, the results appearing in a paper[3] "On the Pliocene Beds of St. Erth," with a list of fossils. Some of their physical

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[1] Dec. 14, 1884. (See Presidential Address, Prof. W. W. Smyth.) 1885–6.

[2] A fatality seems to be attached to the St. Erth shells, as of the pioneers of the deposit, Messrs. Wood, Cornish, Gwyn-Jeffreys, Whitley, Mills, Goodman, Smyth, and R. G. Bell had all departed to the unseen world before the close of half a dozen years.

[3] *Q. J. G. Soc.*, Lond., May, 1886, xlii. pp. 201–215.

speculations are referred to in the sequel. Shortly after Mr. C. Reid, in a preliminary note "On the Pliocene Deposits of North-Western Europe" in *Nature*, Aug. 12, 1886, gave a terse account of the views his observations had led him to conceive, especially with regard to the depth at which the fauna had accumulated, arguing that in consequence of the position of the deposit in relation to the Atlantic swells 40–50 fathoms were necessary. (See post.)

In the Presidential Address (*72nd Report*, Nov. 6, 1885, x., 1885–6, cclx.–cclxvii.) Prof. W. W. Smyth dwelt at some length upon the St. Erth beds, quoting some remarks upon the peculiarities of the fauna sent up to him by Mr. S. Wood; and at the next meeting my late brother, R. G. Bell,[1] read a paper "On the Pliocene Beds of St. Erth," with details of the work done by Kendall and himself, and objecting to Mr. Reid's views; and again at the Manchester meeting of the Brit. Assoc. Adv. Sc. (*57th Report*, p. 718, 1887); his knowledge of the mollusca and their bathymetrical distribution locating the deposit as formed in the laminarian zone at not more than fifteen fathoms depth.

Mr. Reid's views of the St. Erth deposits and its surroundings, and all the information then available, are embodied in his monograph of the "Pliocene Deposits of Britain" (Mem. Geol. Survey, 1890), dealing especially with Kendall's and Bell's paper, and his reasons for differing from them.

[1] Not R. W. Bell, as printed in the *Trans.*, xi. pp. 45–50.

With the exception of a short notice of the visit of the Geologists' Association, London (X. p. 196), and notices of the foraminifera by Mr. Millet (Palæont. Soc., 1895–96), I am not aware of another reference to the St. Erth clays beyond a list of the shells in a paper in the *Proceedings of the Royal Irish Academy*, 1893, by myself.

On the death of my brother, early in 1888, I took up the threads of his work and got together such of the St. Erth fossils as I could find (now in the British Museum), and from his notes, and with the courteous permission of the authorities of the British Museum, Museum of Practical Geology, and the Woodwardian Museum, Cambridge, and Messrs. Thos. Warburton, F.G.S., E. T. Newton, F.R.S., and specimens obtained at St. Erth by myself, I was enabled with the advice and assistance of Mr. Etheridge, F.R.S., to compile the lists referred to above. This list, with additions and considerable revision, is appended to the present paper.

STRATIGRAPHY.

The opening of the sandpit by the side of the road leading up from St. Erth to Carnabeggas (Leland, and Carnhangivis Ordn. Maps) on Mr. Rodd's property has exposed a series of sands and sandy clays not seen in the after-mentioned sandpits on the vicarage glebe land. The rapid alteration in the character of the clays and sands, and the continual modifications they present as they pass along,

renders it difficult to make out their relations to each other, the more so now that so much stuff has been removed. The sections here given very well illustrate this. The first is after Kendall and Bell; the second, taken a few feet away this year; the third, at the southern end of the glebe pit; and the fourth, the Harvey pits,[1] 160 yards away from the last.

1.	2.	3.	4.
Overburden.	Do., 7′.	Do., 12′.	Do., 7′–8′.
Yellow sand.	2′–6″ mottled clay.	Growder resting directly upon yellow and white quartzose sand.	Dirty brown to red sand (pebbly) and 6′ stony sand with ferruginous clay balls, 5′.
Growder.	Sand and sandy clay, 9″.		
Yellow clay.	Growder, 1′–6″.		
Blue clay.	Candle clay, 1′–6″.		
Quartz pebbles.	Blue clay, 6″.	Brown sand.	Mottled clay, 1′–3′
Quartz sand.	Yellow clay.	Growder.	Brown sand, stony, 3′.
Growder.	(Fell in).		Yellow and white quartzose sands, 4′.
Elvan.			Brown sand.

The white sand in the first section is thickest at the side of the pit towards the vicarage, where it is extensively developed, thinning out as the hill slopes. Another section I opened on the other side of the K. & B. section nearer the Trenhayle side of the field gave a much thicker blue clay than in the second section, about 5 feet passing down into a bed of yellow clay cut into some 3 to 4 feet.

Before describing the area investigated, I may briefly refer to the several members of the sections and their physical conditions and structure.

[1] On the Rodd estate.

1. Mr. Whitley's diagram (Plate 1, *op. cit.*) exposes a bed of blue clay directly beneath the head, resting upon beds of fine siliceous red and white sand, the shelly part of the clay lying in a depression therein. Another of Mr. Whitley's section, taken from his note-books, is given in the before-mentioned paper by Mr. Wood. Fig. 1, p. 66 (*op. cit.*), gives a much clearer section, as below the head comes stones cemented by oxide of iron (and manganese), and in order, a tenacious yellow clay, blue clay, fine sand, base not seen, but is stated by the diggers to have gravel and rubble at the bottom resting upon rock.

A general survey of the sections (Sept., 1897) showed a variable thickness of cobb head, or overburden below the surface soil, local where in contact with a rocky basis; but off this, largely intermixed with killas, elvans of several kinds, quartz blocks, and granite, the blocks being of all sizes. In the higher ground, where the rock is a blue (irestone), the head is set in a ferruginous paste; in the felsitic elvan lower down it is a creamy white.

2. Beneath the head (not always present) comes out beds of free sands, white to pale yellow, and red, well exposed on the vicarage side of the pit, and formerly seen at Trenhayle. They are present in the lane cuttings between the stamp mills and the church near the Hayle river, and also in a

plantation near Lelant Station.[1] The sands of the river are different, as Leland, quoted by Davies Gilbert (*Hist. of Cornwall*, vol. i. p. 267), quaintly puts it: "Heyle Haven is shoken with land of tynne works."

These sands pass down into ferruginous sands and gravels coloured by oxides of iron and manganese disposed in horizontal black streaks or bands, known by the diggers as "smoke," or cemented into loose blocks or even a hard pan of various densities and colours, called "cinders" by the workmen.

These sands with their included seams of pebbly gravels are in places as much as 15 feet thick, or even more, in all cases in these localities unfossiliferous. This cementation seems to be characteristic of the "raised beaches" below the head in west and south Cornwall, as De la Beche (*Rep. Geol. of Corn. and Dev.*, p. 430) remarks: "In many places in the south of Cornwall black oxide of iron, in sufficient quantity to render part of the raised beaches black, cement the pebbles and sands composing them firmly together — produced by percolation of the water charged with iron."

[1] Top stuff at Lelant is full of small stones, showing at its base a seam of black *vegetable mould* (earth) 4 to 5 inches thick. Below this is another bed of stony matter mostly quartz pebbles, horizontally arranged, in appearance resting upon red to brown sands with iron smudges, as in the vicarage upper sand. Lelant Church seems to be built upon granite, as a mass of the rock comes out in the floor of the church beneath the Hugh Pawley slab. The church is surrounded by the Towan sands.

In all the sections I have seen these sands come directly below the head, and where no other deposit is present rest directly upon the bed rock, as in the quarries near Carnabeggas and in Mellinear Lane, near the post office.

3. Mottled clay. Yellowish white to light blue, tough, greasy, difficult to work, and of no commercial value. Much of this seems to have been destroyed; being very thick on one side of Harvey's pit it now thins down towards the present end of the vicarage pit, where it is entirely absent, reappearing again about 200 yards off in a bed of some depth, passing into a tough brown clay, which in Harvey's pit may be represented by less compact clays and clayey sands 2 feet to 5 feet thick.

These clays are not absolutely unfossiliferous, as I have found small pieces of shell and one small perfect bivalve, probably from the washing of the clays below. Where these clays are in contact with the clays beneath the line of junction is very irregular, but where these latter are absent the beds rest conformably to the lower free sands.

A thick bed of ferruginous gravel or growder intervenes between the mottled and yellow clays in places, but does not seem to be of any stratigraphical value.

4. The yellow clays, both over and under the intermediate blue clays, belong to one group, and fossiliferous: shells being of the same species in each, but very irregularly dispersed. The yellow or candle clay is soft and unctuous to the touch,

passing down to a dark blue, drying to a sky-blue, and becoming blacker as it deepens. The line of demarcation is fairly plain; the yellow clay on drying splits into coarse laminæ, the blue fracturing irregularly conchoidal. In washing, the yellow is found to contain more fine sand, and the blue more mud and about 1% in weight of angulated stones.

The depth of the blue clay is very variable. The Rev. Mr. Carter, the vicar, tells me he has proved it to 12 feet without reaching bottom, and at less than 10 yards off I found it not more than 6 inches, and about 4 feet between the two cuttings.

As in two of the pits I opened yellow clay was found below the blue, the variation in colour may be, as suggested, due to oxidation, now in progress, as the operations of late years in removing the covering beds and the general disturbance of the soil have facilitated atmospheric action, and through water draining from the higher ground. This I proved by experience, as after a very heavy rainfall the lower portion of one of my pits was daily flooded by water percolating from a higher level till the latter had drained off.

The fossils are very irregularly distributed in the clays. Most of the bivalves occur in fragments, and are ascribed to the crushing teeth of the wolf and similar fish who have fed upon them. Much of the damage may be due to something in the clays inimical to the preservation of the tests acting upon the shells; the sharpness

of the fractured edges is remarkable, and yet in the yellow clays they are very rotten and easily disintegrated, the fragments often lying in juxtaposition. Microzoa are scarce.

The chief shells in the yellow clay are Nassa serrata(?) Turritella, Cerithium or Bittium, and two or three trochi, pectens, tapes, etc., always in a bad state. I found the higher part of the blue clay more prolific than the mid-portion, which seemed utterly free from anything, however fine or small, or but few in number, as both Mr. Wood and myself unfortunately discovered. Below this they abound in some places, and Mr. Carter tells me that in ground opened a few years ago the ground was fœtid as with the odour of stale fish.

Where penetrated the clays are found resting upon fine free siliceous sands "white and red" (Whitley), yellow and purplish fine quartzose sand (Kendall and Bell). At the opposite end of the vicarage pit and in Harvey's pit a thick white and bright yellow sharp sand, degenerating into a coarse brown sandy clay of inferior quality and purity, occupies the lower part of the sections, an irregular bed of reddish gravel alone separating it from the head in the vicarage pit, and a mass of sand some 15 feet to 20 feet thick in Harvey's pit. A few light and red clay pebbles occur in the sands and lower beds here, but I have not noticed them in the other exposure.

Kendall and Bell show in their section a layer

of quartz pebbles between the lower sand and the blue clay, and, although they do not appear in the free sand in the opposite face, yet in the sands at the entry to Harvey's pit and the free sand into which it passes horizontal layers of this stone are present. All the stone layers are intermittent, including those which, as I am told by Tregenza, the most experienced sand-digger in the village, serve to distinguish the several beds of clay and sand. The free sands both above and below are much alike in texture and nature, but only the higher ones show traces of the percolation of iron-containing waters.

SITE AND POSITION.

Standing a little above the end of the village facing the north-east, where the road rises, the observer is on a narrow ridge or spur of blue elvan or irestone.[1] To his right hand, near the old Danish fort, is a steep-sided rock face by the roadside; another steep face on his right front is known on which the vicarage is built, extending to Trenhayle; and to his left the road continues down the main street to the river, rising again beyond the bridge towards Treloweth, intercepting in its way a steep ridge or dyke of felsitic or porphyritic elvan (both seen in the roadway near the cross), rapidly dipping to the north-east down the hill, where it is exposed in a deep quarry by

[1] The term "irestone" or "ironstone" is a name given to various rocks. See R. W. Fox, *Trans.* vol. iv. (1838) p. 28.

the roadside, passing below the level of the surface, sand and coarse growder overlying it.

The trough thus formed by the hornblendic bands, or irestone, and the felsitic elvan dyke lies across the north-west face of the hill, opening slightly to the east of north, its broadest part barely 400 yards in width, and from the St. Erth road to where the blue clay was seen at Trenhayle about 380 yards[1]—a line drawn from the road, passing through the pits and Trelissick farm to the Phillack backwater. Of the lower deposits (*i.e.*, sand and shelly clays) there are no traces in the line if continued backwards from the road in a line to the high grounds of Trewinnard and Trevelsa across the Hayle river.

Mr. W. W. Smyth suggested that between the sea and Relubbus "many places might very likely harbour a continuation of these deposits," but, so far as I can ascertain, there is no evidence of its former extension in this direction, nor in the expansion of the deposit across the Hayle estuary to Trecrobbin hill, as given in Mr. Wood's second diagram. I have found a clay at Trewinnard and at Lelant, but these are estuarine clays of more recent date. Another stony clay nearer Rosevidney seems to be the equivalent of the stony earths everywhere associated with the overburden, but nowhere can I find or hear from any miner, farm

[1] These dimensions are approximate only, but are sufficiently near for the purpose.

hand, or sand-digger that anything like the St. Erth clays has ever been found.

Bearing in view the position of the St. Erth trough to the Hayle river estuary on one side, and Mount's Bay on the other, as seen from the top of the hill above Carnabeggas, it is not so clear that the shelly clays have anything in common with the strait supposed to have existed between them, the mouth or opening of the trough or inlet opening into St. Ives Bay—the Towans at Phillack not then being in existence.[1] If any deposits of the shelly clay are still in existence they may be found on the higher ground north of Marazion marsh; but as so much mining has gone on in this direction without showing any signs of these clays, there is little hope of such a find.

For the St. Erth clay, as I have differed from my predecessors in the extent of the deposit, I offer another explanation. Believing in my brother's view of the depth at which the fauna lived and died, I suggest that when the relative positions of sea and land were convenient the lower sands were driven into a recess or shallow inlet, hardly a fjord, forming a sloping beach, the sands thickening against the end barrier (viz., the spur now leading down from Carnabeggas to the cross elvan dyke, on which a bed of mud was gradually laid down from low tide mark to 15 fm., becoming sandier as it deepened or thickened into the

[1] These appear (see CARNE, *Trans.* iii. 47) to have come into existence between A.D. 410-450.

higher yellow and mottled clay, into which it passed—at times nearly an impure sand altogether —much as a recent sea beach often looks.

The shelly clays are contained in a very small area—a shallow, irregular, depressed triangle, thinning out at the edges to a few inches, and at its deepest 12 feet to 14 feet, the point coming out at Moor meadow by the roadside. From hence to Trenhayle, where it was seen on one side of the sandpit, it runs to about 280 yards, to where it ends in the Vicarage pit;[1] and on the shorter side, from Trenhayle to the Vicarage pits, 138–140 yards=to about 20,000 superficial yards, or taking the average thickness at 6 feet, 40,000 cubic yards in bulk; the distance from the roadway up St. Erth hill to Trenhayle section through the pits being about 350 yards.

The clay dips to the north very rapidly; at Moor meadow it stands 50 feet above O.D. In the Vicarage pit it is 90–100 feet, or a fall of, say, 40 feet in less than 300 yards. This fall I found very troublesome, as after opening a pit the top of the clay formed a good landslide for the overburden after heavy rain.

There seems to be no evidence to connect the scattered gravels, at Crousa Down 360 feet O.D., on Crowan 400 feet (Porthlevery), St. Agnes Beacon 375 feet, which, as most observers notice, may be of any tertiary age or even older. It is doubtful if the latter are even marine, although the

[1] About 300 yards.

description of the deposits by Messrs. Davies and Kitto (*Trans.* ix. p. 196) as partly a "clay of two kinds, one a bluish candle clay without fragments, and a coarser fireclay, less washed perhaps, and a pure siliceous sand of all colours tinged with iron, containing pebbles of local rocks up to a ton in weight," reads like as if a sea beach was referred to. Messrs. Davies and Kitto are uncertain if these were not deposited in an arm of the sea to which the river had access, and Mr. Ussher thinks the circumstances are more consonant with fluviatile action. The St. Agnes beds may not even be of the same age as Crousa and Crowan, but probably are connected with the elevated deposits 300 feet on Carn Brae near the head of the beacon, described by Dr. Boase as a fine siliceous sand, about 10 feet in depth, without organic remains (*Trans.* iv. p. 296). The proposition that the St. Agnes sands represent a beach of the St. Erth period depends upon the submergence of the latter to 40–50 fathoms, which is not justified by the fauna.

Both Messrs. Wood, Kendall, and R. Bell were disposed to collate the deposits here as co-equal to the older portion of the Red Crag of East Anglia, viz., that at Walton-on-the-Naze. Mr. Reid makes it much older, placing it on a level with the Lenham pliocene sands. Of the shells upon which the former opinions were based, the large Nassa is only generically related to the usual Crag type, although many examples from Boyton closely approximate to the St. Erth shell; yet the Crag

form does exist in the pre-glacial sands of Wexford, and in those of the north of the Isle of Man. The Columbella is neither the Crag or Isle of Man species. Nassa granulata is an Irish shell, not rare in the Ballybrack Bay cliff,[1] Co. Dublin, and the Melampus pyramidalis is closely akin to an Italian shell also. It occurs at Wexford. Mr. Reid's suggestion that the Melampus, a shore-frequenting shell, was drifted in or floated from a distance, may be challenged, as several examples of another species are known from the clays. Many shells occur in common with the East Anglian beds, but such may be expected, as both faunas range back to an earlier period, and of south European origin, travelling northward by different ways.

In analysing the lists of shells given further on, it may be noticed that of the 250 species 50 per cent. are only known from one to three examples, about 15 per cent. are fairly common, 5 per cent. plentiful; and, considering the small amount of ground available for present research, it may be predicated that if at any time further exposures are accessible to the student the lists will be greatly augmented, and further evidence necessitate a revision of the species. First may be noticed the complete absence of either boreal or northern species—the supposed fragment of Buccinum undatum (?) being of a Cassidarian type; and second, the prevalence of south European species, a

[1] Associated with Peden glaber and Woodia digitaria. (See *Rep. Brit. Assoc. Adv. Sc.*, 1887–90, "Manure, Gravels, &c.," A. Bell.)

number of these being extinct forms. I append here two lists of species, the first of non-British shells common to St. Erth and the Crags; the second of shells confined to St. Erth of S. European types, recent or fossil.

Of the 90 species in the lists still found in British seas, or in the Atlantic that pass into northern waters, every one without exception passes southwards, the identification of Cardium strigilliferum, *Wood*, with C. elegantulum, *Möll*, being at least doubtful, even if the southward range of the latter was definitely known. Its home is in Arctic waters, and it comes down to Norway. The characteristic Ledas, Astartes, Fusi, Buccinidæ of the north are all unknown.

The letter F signifies species only known in a fossil state.

I. CRAG SHELLS.

F Cypræa avellana
F „ affinis
F Voluta sp. (*var.* St. Erthensis)
F Nassa granifera
F „ granulata
F Cerithium tricinctum
F (Bittium) punctulum
Natica millepunctata
F „ consors
F „ catenoides
F „ varians
F Nodostomia culimelloides
F Chemnitzia euterpe (?)
F „ plicatula
Turritella triplicata
F Eulimene pendula
F „ terebellata
F Lacuna (?) suboperta
F Collonia naticoides
Trochus noduliferens
F „ bullatus
Turbo spheroidea
Scaphander punctato-striata
F Melampus pyramidalis
F „ fusiformis.
F Ostrea plicatula
F „ ungulata
Pectunculus pilosus
Nucula proxima
Cardium strigilliferum
Cardita corbis
Woodia digitaria
Astarte parvula
Montacuta truncata
Lasæa pumila
Kellia orbicularis

II. SOUTH EUROPEAN.

F Columbella erythrostoma (C. sulcata of K. and B.)
Nassa Mutabilis
F „ solida
F „ Warburtoni
F „ Dertonensis
F „ Perrieriæ
F „ Touerneri
F „ semireticosa.
F „ v. Emiliana
F „ Jani recticostata
F Cominella aquitanicum
Cassidaria echinophora
F Murex funiculosus
„ rudis
Nesæa candidissima
Euthria cornea
F Pleurotoma Hoernsii
Bittium reticulatum
var. trinodosa
Natica millepunctata
F „ v. Beyrichii
F Chemnitzia gracilis
F Rissoa Ehrenbergii
„ Montagui
F „ curta
F „ clotho (whitleyi)
Solarium conulus
Trochocochlea turbinata
Trochus elenchoides
Ringicula striata
F Pecten Brocchii
Limopsis minutus
Cardium erinaceum
F „ Hornesianum
„ papillosum
Astarte M^c^andrewi
Cardita aculeata
(F) Venus multilamella
Petricola lithophaga

Of the 75 species in the above lists 28 are still living in South European waters, 36 are South European fossils, and of the remainder 3 are uncertain species, leaving about 30 forms at present peculiar to St. Erth and S. Europe.

The only British deposit equally rich in South European shells, without any admixture of northern forms, containing as many as 200 species, at Selsey, near Chichester, Sussex,[1] affords no help in determining the age of the St. Erth beds, as all the

[1] *Rep. Trans. Phil. Soc., Yorkshire*, "The Selsey Beds" (A. Bell), 1893.

mollusca are presumably recent; and we must, therefore, seek for guidance elsewhere. Turning southwards to the Norman Cotentin, the nearest available land, I am informed by my friend, Mr. G. Dollfus, who is perhaps the greatest authority on the pliocene deposits of France, that "you have in St. Erth exactly the same pliocene fauna as we have at Gourbesville, in the Cotentin." "We have lately discovered in the Vendée, near the estuary of the Loire, very fine, very extensive, and fossiliferous beds exactly similar to the Cotentin beds—the fauna is the same."

The presence of a South European fauna in this corner of Britain implies a water-way by which it entered, and, looking at the map of present Europe and the contour of the land, it is by no means easy to arrive at any satisfactory conclusion as to where this was. Dr. Gwyn-Jeffreys considered that the Straits of Gibraltar were closed and a broad line of communication opened between the Atlantic at Bordeaux and Narbonne in the Mediterranean, in the line of the Languedoc canal. Kendall and Bell suggest a gulf extending across south-west France, then cutting off the Finistère district, throwing an arm across to the Cotentin, and thence in a westerly direction to St. Erth. There is every reason to suppose that at this period there was no opening to the north, since no northern shells are found; and as these do occur in the south-east of Ireland, at Wexford (see *ante*), it may be inferred that

the North Sea was not then open, but a plain occupied its channel, then much narrower.

A submergence of the St. Erth clay to its normal depth, 15 fathoms, would open a tortuous channel westwards of no greater depth, if so much, and a very deep fjord up the present Hayle valley opening into St. Ives Bay, the whole sea studded with islands and rocky reefs.

Mr. Dollfus, writing to me on this matter, says: "There is no way crossing south of France for the sea during the last geological periods. All the depression of the Canal du Midi is full of miocene fresh-water deposits. No one pliocene shell had been found in the basin of the Gironde, only on the eastern side not very far from the Mediterranean shore, and not very highly placed, are pliocene deposits similar to the Italian beds." The Lisbon deposits are also all miocene, not pliocene, and only littoral.

This appears to complicate the question; and the next question arises—was the deposit accumulated *in situ* or not? Several opinions have been offered to me, which may be briefly discussed. One cause I have had suggested to me is that it is Mediterranean earth brought as ballast by the early Phœnician traders, and shot out here. The presence of the overburden refutes this idea. Another is that it is an interloper—in fact, a mass of stuff introduced or carried by drifting ice from the south and stranded here. There is something to be said for this view. The flotation of large

blocks of foreign erratics drifted from France, or destroyed beds in the English Channel on the Sussex coast, is well known, and at an earlier period masses of frozen sand have been introduced into the glacial clays on the Yorkshire coast, and a bed of Lincolnshire oolite several acres in dimension has been found a little to the north of London. So there is nothing to be urged against the possibility of such a bed as the St. Erth clay coming into the Cornish area in this fashion, and being sucked into this bight by the inset of the current. The Rev. Osmond Fisher, whose researches in the dynamics of geology are so well known, writes me that 55 feet of water would be sufficient to float the mass of blue clay, the ice being 50 feet thick.

On the other hand, while the wetness of the clay and the nature of its contents give no pointer either way, the imbedded stones seem to be of much importance. These amount to about 1 per cent. of the weight of the whole, and are, so far as I have found, of local rocks, a little killas, the felsitic elvans of the lower wall, and the blue irestone of the upper wall; clay pebbles, indurated and iron stains, as in the older sands in Harvey's pit iron vein-stone, and as they occur at all levels seem to be as genuine inclusions as the shells themselves, which occur in all stages of growth and perfectly unworn, some of the naticas having the opercula inside the mouth still. Mr. Dollfus's statements and discoveries confirm the usual

opinion that the shells lived and died where they are found.

From the position and elevation of the deposit, and the relation of its fauna to the Zanclean of Prof. Sequenza, I am inclined to class the deposit as of mio-pliocene date (Messinian), and to have been raised to its present position anterior to the deposition of the glacial beds of the south of Ireland and the opening of the Irish Channel to the north.

The length of time occupied by these changes is not to be estimated by the thickness of the deposits, but by the slowness with which faunas change.

There is a general opinion that glacial conditions only affected the extreme west of England in a small degree, ice being little concerned, yet local glaciers would probably have been existent. My brother notices a stratum of sand exhibiting crumpling or curling up, as in the eastern contorted drift, in one corner of the Vicar's pit.

Mr. Pengelly (*Trans. Devon Assoc.* 1873, *et seq.*) has given several instances of travelled boulders and scratched stones in South Devon, ranging from 70 to 200 feet above O.D., some of considerable weight and dimensions, one as much as 17 × 10 × 5 feet = 60 tons. Quartz rocks (locally termed Whitakers) are found resting on killas at Tamerton Foliot, which must have come from a distance, as the parent rock does not occur in the district.

One such block is noticed as lying in shingle beneath the erratic-raised beach at Barnstaple Bay $7 \times 6{\cdot}3 = 135$ cubic feet, and rounded at the edges and angles. A similar flesh-coloured granite occurs on Dartmoor, but does not yield such large blocks when broken out, say Messrs. Freeman of the Penryn Works.

Mr. C. W. Peach (*Trans. Royal Geol. Soc., Cornwall*, ix. (1871) p. 105) notices blocks of quartz of all sizes, which he considered could only be ice-borne, lying thickly under the Nare point in St. Keverne. The way some of the huge blocks are seen resting on others on the sides of the granite hill of Trencrom, and the many massive isolated blocks scattered about the elevated country nearly everywhere, seem to require some agency for their transport. I am not aware under what circumstances the many massive blocks were tumbled down at the side of the Hayle estuary near the Foundry, but they closely resemble in the disposition of their fall the masses of granite I have seen on the Irish coast between Ballybrack and Bray, Co. Dublin.

None of these scattered Cornish blocks appear to have been striated or scratched, or if so, have not been noticed. I saw just lately on a piece of waste ground near Trenedris, on the slope of the hill going down from Carnabeggas to Porthcolumb, a large mass of blue irestone, one side of which was fluted or deeply furrowed, the furrows lying all in the same direction.

Mr. Peach again mentions finding on the summit of the pile above Peravea a polished surface, not a slickenside, as it was on the upper face, specimens being presented to the Society's Museum. A block of stone lies at the present time, or did lately when I saw it, by the side of the pathway from Trelissick Farm to St. Erth smoothed and polished on one surface. I submit the subject with some diffidence as worthy of further consideration.

Finally, I have to thank the Rev. the Vicar for the facilities afforded me in excavation, and to acknowledge with deep gratitude the ready aid and kindness which met me at every turn in the west from all with whom I came in contact by letter or in person; and to John Davies Enys, Esq., F.G.S., and J. B. Cornish, Esq. (the President and Secretary of the Society), especially.

The institutions and collections containing the *specimens* upon which the names are founded in these lists are given in the text, thus:—

Brit. Mus. for *British Museum.*

Mus. p. Geol. for *Museum of Practical Geology*, with which is incorporated the gatherings of E. T. Newton, Esq., F.G.S., presented by him to the Museum.

Mus. R. G. Soc., Cornw., for *Museum Royal Geological Society of Cornwall.*

Woodw. Mus. for *Woodwardian Museum, Cambridge.*

Warbn. Coll. for *Collection of Thos. Warburton, Esq., F.G.S.*

Hudl. Coll. for *Collection of W. H. Hudleston, Esq.*, F.R.S.

Harm. Coll. for *Collection of F. H. Harmer, Esq.*, F.G.S.

The *locale* of the figured specimens are given with the plates.

UNIVALVES.

CYPRÆA (TRIVIA) AVELLANA, Sow. L. 18, b. 13 mm. Brit. Mus.

CYPRÆA (TRIVIA) EUROPEA, Mont. L. 7, b. 6 mm. Brit. Mus.

CYPRÆA (TRIVIA) EUROPEA, var. AFFINIS, Duj. L. 10, b. 8 mm. Brit. Mus.

CYPRÆA (TRIVIA) EUROPEA, var. DUBIA, Eth. and Bell. This may be an aberrant variety of the ordinary *Trivia*, the ribs running straightways across the body of the shell. (?) Brit. Mus.

VOLUTA ST. ERTHENSIS, Eth. and Bell.

A pillar is the only portion of the shell we know of. As it carries the folds more horizontally than either *V. lamberti* or *V. auris leporis*, we separated it as distinct for the present. Woodw. Mus.

DEFRANCIA LINEARIS, Mont. L. 6, b. 2½ mm. Brit. Mus.

PLEUROTOMA (MANGILIA) COSTATA, Don. Mus. p. Geol.

PLEUROTOMA (MANGILIA) GWYNIA, Eth. and Bell.

Shell spindle-shaped; whorls 5–6 convex, crossed by strong curvilinear ribs; the upper whorls exhibit coarse spiral striæ, but faintly indicated in those succeeding. Aperture long, narrow, somewhat angulated at the upper extremity; canal short and open; apex and nucleus perfectly smooth. It may be

distinguished from the other costated *pleurotomas* by the obliquity of the ribs, and its greater breadth in proportion to length. Dr. Gwyn-Jeffreys was the first to recognise it as a new species. No. G. 4033. Brit. Mus.

PLEUROTOMA (MANGILIA) COARCTATA, E. Forbes. Warbn. Coll.

PLEUROTOMA COSTATO STRIATA, Wood.

A shell like *costata*, but with eight equidistant spiral striæ on the body whorl (three on the penultimate), traversing both costæ and interspaces. Whorls more convex, and shell larger and broader. The striæ are not always so distinct; ex. Woodw. Mus., Brit. Mus.

PLEUROTOMA BRACHYSTOMA, Phil.

There are several shells in various collections referable to this group of *Pleurotomas* which appear to be new to science; whether merely varieties of one type-form it is at present doubtful. The following seem to be fairly well-defined forms. The above shell corresponds more to Forbes' and Hanley's figure than to those of Jeffreys and Wood. (Crag. Moll.) Brit. Mus.

PLEUROTOMA (MANGILIA) CORNISHI, Eth. and Bell. Pl. 1, fig. 10.

Ovately fusiform; spire, short; apex, blunt; whorls, 6–7, convexly angulated at shoulder; the stout longitudinal ribs crossed by prominent striæ; aperture expanded above, narrowing to a short open canal; outer lip thin, inner lip slightly reflected. Named in memory of the late T. Cornish, the earliest worker in the St. Erth deposit. Length, 6 mm.; breadth, 4. B. 1½ mm. Mus. R. G. Soc., Cornw.

Mr. Hudleston's collection contains a small shell which we cannot identify, except as a *mangilia*. It is a very young shell, four or five whorls only, a short

mouth, twisted canal, whorls convex, finely and closely ribbed.

PLEUROTOMA HŒRNESII, Mayer. *Journ. de Conch.*, 1858. Pl. 11, fig. 1.

The St. Erth shell has the canal rather shorter than the type-form; spire, very produced; whorls, 9–10, narrow flattened; convex, depressed above; aperture, short. L. 10, b. 3 mm.; L. 9, aperture 3 mm.

PLEUROTOMA KEEPINGI, Eth. and Bell.

Shell turriculate, spire long, whorls 7–8, ribs straight, broad, canal short, aperture long and narrow. May be related to *P. hörnesii*, but looks broader, and has shorter and more convex whorls; pillar slightly enamelled, exposing a long narrow chink. We have named it after our old friend Mr. Keeping. L. 9, b. 3 mm. Woodw. Mus. Mus. p. Geol.

PLEUROTOMA COMPACTA, Eth. and Bell.

A very small shell, angulated and swollen in the body, short spire, and canal of equal length. (?) A young shell.

PLEUROTOMA COMMUNIS, Eth. and Bell.

Shorter than *P. Hörnesii*, and broader in proportion, with a shorter mouth and more bulbous whorls than *P. Keepingii*. Mus. p. Geol.

MUREX FUNICULOSUS, Bors. Michelotti mon. del. murex, No. 24.

L. 30, b. 17 mm. Spec. in Brit. Mus.

MUREX RUDIS, Bors. (f. Hoernes, t. li. fig. 6). Pl. 1, fig. 3.

It may be the *Pseudomurex ruderatus Monter.* (See Dr. Sturany, *Denks. Akad. Wissensch. Wien.*, 1896.)

LACHESIS MULTILINEATA, Eth. and Bell. Pl. 1, fig. 9.

Whorls 5–6, flatly convex; apex blunt, smooth; suture deep, aperture half length of body whorl, outer lip thin, slightly expanded, pillar nearly straight,

canal short, ornamented with close-set spiral lines; no costæ. Brit. Mus.

LACHESIS (NESÆA) CANDIDISSIMA, Phil. En. Moll., *sic.* t. xi. fig. 18.

A pure ivory-white shell. L. 10 mm. Brit. Mus.

FUSUS (?) TENTATIVUS, Eth and Bell.

A small diamond-shaped shell, encircled with knobbed ridges; apex cancellated. Larger and older examples may refer it to the *genus Engina*, one of the *Turbinellas*.

EUTHRIA CORNEA, L. Pl. 1, fig. 2.

The St. Erth shells differ from the recent type in the absence of the broad, shallow groove in the upper part of the whorls below the suture. Brit. Mus.

COLUMBELLA ERYTHROSTOMA, Bonani. (*C. Sulcata*, K. and B.) Pl. 1, fig. 1. Bellardi Mon. di. Columb., t. i. fig. 4. Mus. p. Geol.

L. 26 mm., body whorl 18 mm., b. 10 mm.

BUCCINUM (?) (COMINELLA) AQUITANICUM, Mayer, *Journ. de Conch.*, 1858. Pl. 4, fig. 2.

Whorls 4–5, semi-convex, apex blunt, spire conical, costæ broad, rounded, shallow interspaces, wide columella, lip slightly reflected, canal open, colour yellowish, L. 13, b. 8 mm. Brit. Mus.

CASSIDARIA ECHINOPHORA, L.

Upper whorls or spire above the mouth only preserved. Hoerne's figure, t. xvi. fig. 4 (Vienna basin), represents our shell, more so than recent examples. Brit. Mus.

NASSA MUTABILIS, L. Pl. 1. fig. 4.

There are several well-marked varieties in the St. Erth shells, which run larger than the recent type-forms to which they clearly belong. L. 25, b. 20 mm. Brit. Mus.

NASSA MUTABILIS, var. ST. ERTHENSIS, S.V.W. Pl. 1, fig. 5.

A more elongated shell than the type figured above; smooth on inner lip, less keeled on shoulder; enamel thinly spread over pillar. One very large example in the British Museum (*N. gigantea*, R. G. B. MS.) is striated all over. Brit. Mus.

NASSA SOLIDA, Wood. Pl. 1, fig. 6.

A solid massive shell, 6–7 whorls, blunt apex, usually eroded, whorls convex to gibbous, channelled or depressed at the shoulder, denticulate on inner lip, with 10–12 short ridges, pillar incurved, canal open, deep, surface smooth, with fine striæ beneath the glaze, columellar lip well reflected; variable in proportions. It does not agree with any known continental species. L. 25, b. from 19 to 25 mm. Brit. Mus.

NASSA RECTICOSTATA, Bellardi. Pl. 1, fig. 8.

M. Dolfuss writes me that he considers this shell to be the same as *N. costulata*, Ren. It is a variable shell in its proportions, in the number of denticles in the inner lip and in the slope of the ribs, which in adult shells do not continue to the base of the body whorl. L. 5, b. 4 mm. Brit. Mus.

NASSA TOUERNERI, Stefani and Pantanelli.

This little nassa may be a variety of *N. recticostata*, to which it has considerable affinity; it differs in proportions of length to breadth, with a shorter and blunter spire. It agrees with a shell sent us from Siena by Dr. Foresti. L. 6½, b. 4 mm. (?) Warbn. Coll.

NASSA DERTONENSIS, Bell.

A doubtful reference, as the shell is imperfect. Mus. p. Geol.

NASSA (UZITA) SEMIRETICOSA, Eth. and Bell. Pl. 1, figs. 7, 7*a*. (Serrata K. and B. and E. and B.)

This is one of the commonest of the St. Erth

shells. It has been ascribed to *N. serrata*, Broc., but is "a longer and more solid shell than most of the continental forms of serrata." (R. G. B. *in litt.*) It comes near to some of the polymorphous forms of *N. reticosa*. It differs also in size and the greater development of the columellar lip from *N. reticulata*. M. Dolfuss suggests to me that it might be called *N. reticosa*, var. *reticulata*—a name I would have adopted, but fear it being confused with the recent species of that name. Hoernes' figure (*N. prismaticum*, t. xii. figs. 13, 14) represents our shell very much, especially as regards the nodulation. Bellardi makes too many species out of this group of Nassas. L. 30, b. 15 mm.

NASSA EMILIANA, May., is another variety, only shorter and broader, and rather finer cancellated.

The Crag *N. reticosa*, also found in the pre-glacial Wexford gravels and the Isle of Man (age uncertain), may represent one end of a lengthened chain, Brocchi's species (*N. serrata*) the other, the St. Erth forms being intermediate. Some Boyton (Suffolk) crag shells come near ours, but do not quite agree with it.

The shell exists from the earliest stages of growth in the St. Erth clay, and is very variable in outline; ovately oblong turriculate, spire elevated, apex blunt, whorls 8–9, convex, rugosely angulated, with 12–15 broad bands on the body, and crossed by stout flexuous ribs, producing strong nodulation; bands separated by deep grooves, mouth ovate, emarginate; denticulated inside outer lip, notched at lower portion of base; canal broad, deep, and open. The spire is more obtuse in the younger shells, and the interior denticulation develops early in life. Some shells are a yellowish white, with colour lines in the grooves. Brit. Mus.

NASSA (UZITA) GRANULATA (?). Sow., *fide* S. V. Wood.

K. and B. consider this and the preceding shell as the same species; Hoernes as both equal to *N. incrassata.* We do not agree with either view. *N. granulata* is one of the last surviving pliocene shells known in pleistocene deposits, being present in the Ballybrack Drift, Killiney Bay. R. G. Bell thought the fragments agreed better with *N. granifera.* I give it with much doubt. Brit. Mus.

NASSA (UZITA) GRANIFERA, Duj.

L. 8, b. 5 mm. Brit. Mus. Warbn. Coll.

NASSA (UZITA) JANI, Mayer. *Journ. de Conch.*, 1873. Pl. 6, fig. 6.

The shell agrees with Mayer's figure, but may be only an elongated form of *N. granifera;* it has some denticles or folds on the lower columellar lip, and several on the inner lip. It does not agree, on comparison, with *N. granulata.* L. 11, b. 5 mm.

NASSA (UZITA) PERRIERIÆ, Bellardi (*op. cit.* t. vi. fig. 15).

If a sufficient number of specimens were available for comparison, it is probable that *N. granifera*, *N. jani*, and this would be found merely variations of one species. As it agrees with Bellardi's figure I leave it with his name. L. 10, b. 6 mm. Brit. Mus.

NASSA (UZITA) SEMISTRIATA (?), Broc.

Two examples, immature, seems to belong to this very variable species. L. 15, b. 9 mm. Mus. p. Geol.

NASSA (UZITA) WARBURTONI, Eth. and Bell. The same type of shell as *N. semistriata*, minus the *sulci.* It closely resembles *N. Josephina, Foresti.* Warbn. Coll.

NASSA SULCATA, Eth and Bell. Pl. 1, fig. 11.

Shell turriculate, spire short, nucleus depressed, blunt, whorls 6, convex, suture deep, body whorl swollen, ribs on upper whorls straight, on body whorl slanting from left to right; interspaces equal to ribs in breadth; the whole curved by deep sulci; outer

lip plain, inner slightly reflected over pillar which has a narrow ridge at base ; canal broad, twisted.

This is another of these incrassate types. It seems intermediate between *N. Jani* and *N. turricula.* Mayer, *Journ. de Conch.*, x., fig. 5. L. 6, b. 3 mm.

CERITHIUM TRICINCTUM, Broc. L. 30, b. 11 mm. Warbn. Coll.

CER. (BITTIUM) RETICULATUM, Da. Cos. A very few examples mixed with the next form. L. 10 mm., b. 2 mm. Warbn. Coll.

CER. (BITTIUM) RETICULATUM, var. TRINODOSUM, Eth. and Bell. (*pseudoreticulatum*, S. V. W. MS., Eth. and Bell.) Pl. 1, fig. 13.

This abundant shell differs from the type in only possessing three rows of nodules instead of four, and has a longer spire and deeper suture. The base is encircled with two thin prominent striæ. A fine thread is usually present between the two top rows on the body whorl, the striæ numbering 10–12. It is the most plentiful shell at St. Erth. Hoernes figures a shell of this type of ornament as *C. pygmæum*, Phil., but it is a smaller and different type of shell. L. 12, b. 2 mm. Brit. Mus. The shell is in some examples ivory or dead white in colour. M. Dolfuss writes—"Perhaps it is a new species."

Dr. Jeffreys says of *C. reticulatum*, it "might be the *Trochus punctatum*, *L.*, if it had not been *described* "*anfractibus serie triplice punctatum.*" Possibly Linné might have seen a specimen of our shell, as I have seen two examples very like it, picked up on our southern coast. The basal ridges of the St. Erth shell separate it from the common form.

CER (BITTIUM), var. CRASSICOSTATA, Eth. and Bell.

This is probably a variant of the common form, without nodules, only four or five costæ, confluent from apex to base.

CERITHIUM RETICULATUM, var. PUNCTULUM, S. V. Wood (not *variculosum Nyst* as in *C. Moll.*, altered in 2nd supplement). Pl. 1, figs. 12 *a*, *b*, *c*.

The St. Erth shells agrees with Mr. Wood's figure and description; the four lines of nodules relate it to the type. Warbn. Coll.

TRIFORIS PERVERSUM, L.

Base rounded. Brit. Mus.

TRIFORIS ADVERSUM, Mont. Warbn. Coll.

Base angular. Dr. Jeffreys and Weinkauff consider these as one species; Seguenza and Monterosata as different.

CERITHIOPSIS MINUTUM, Eth. and Bell.

A narrow aciculate shell, with straight sides and flattened whorls.

ADEORBIS (COLLONIA) NATICOIDES, Wood.

More globose and elevated than the above, smooth with channel on the outer side of the deep umbilicus, bounded by well-marked ridge.

ADEORBIS OBLIQUATA, Eth. and Bell.

Small, flat, smooth, wide mouth, and large umbilicus.

NATICA MILLEPUNCTATA, Lam.

Umbilicus large, open ridge, thick and massive. This form does not occur in the English Crags; a large series like that at Cambridge tends to bring this and the next together.

NATICA MILLEPUNCTATA, var. MULTIPUNCTATA, Wood. Pl. 2, fig. 1.

Smaller umbilicus and ridge; columella flatter, showing impression of operculum in some specimens.

NATICA CENSORS, Wood. Pl. 1, fig. 3. (Operculum.)

One of the umbilicated group of naticas, but much rounder than the above, with but a small callus in the umbilicus. The British Museum example had the operculum inside the mouth, as in the Crag shell

figured by Mr. Wood. I have seen it from the Italian pliocenes.

NATICA BEYRICHII, *v.* KOEN. (Das. Miocan N. Deutschlands. T. v. fig. 1–3.)

In this the umbilical ridge is very small and thin. A large series would probably collate it with *N. Cirriformis*, Wood.

NATICA TENUIS, Eth. and Bell.

Differs from *N. Millepunctata* in its greater globosity, tenuity, length, acuteness of spire and apex, and the lesser amount of enamel. L. 11, b. 10 mm. in Brit. Mus. L. 18, b. 16 mm. in Woodw. Mus.

A number of species might be constructed out of these open umbilicated naticas, which vary so much in shape and texture.

NATICA MONTACUTI (?), Jeffr. Hudl. Coll.

The St. Erth shell comes nearer to this species than any I have seen of the group. Its determination is not so satisfactory as might be. L. 10, b. 9 mm.

NATICA (NEVERITA) CATENOIDES, Wood. Pl. 2, fig. 6.

L. 33, b. 30 mm. Brit. Mus.

NATICA (NEVERITA) PROXIMA, Wood.

L. 17, b. 15 mm. Hudl. Coll.

NATICA (NEVERITA) SORDIDA, Phil. Pl. 2, fig. 2.

These two differ so slightly that they may be considered as the same species, *N. proxima* presenting but few slight unimportant variations from *N. sordida*. L. 26, b. 20 mm. Brit. Mus.

NATICA (NEVERITA) VARIANS, Duj. Pl. 2, fig. 5.

In this the umbilicus is larger and more few than the above, the enamel thickening at the lower part of the pillar, and forming a thick callui above. L. 28, b. 22 mm.

NATICA (POLINICES) WARBURTONI, Eth. and Bell. Pl. 2, fig. 4.

Conic ovate, spire elevated, whorls 6–7, slightly convex, apex pointed, suture definite, umbilicus long, open, not broad; enamel well spread, thick above umbilicus; aperture lunate. L. 25, b. 16 mm. Warbn. Coll.

EULIMA POLITA, L. Brit. Mus.

A perfect example, with bent spire, is in the Warbn. Coll.

EULIMA (LEIOSTRACA) SUBULATA, Don. L. 9 mm.

EULIMA INTERMEDIA, Cant. Woodw. Coll. L. 3½ mm.

EULIMA STENOSTOMA, Jeffr. Warbn. Coll.

EULIMA STALIOI, Cant. (*glabella*, Wood). Brit. Mus. L. 2 mm.

EULIMA GRACILIS (*E. distorta*, var. *gracilis*). F. and H. L. 3 mm.

ODOSTOMIA ACUTA, Jeffr. L. 2–3 mm. Brit. Mus.

ODOSTOMIA PALLIDA, Mont. L. 2 mm.

ODOSTOMIA PLICATA, Mont. L. 2 mm. Brit. Mus.

ODOSTOMIA OBLIQUA, Alder. Warbn. Coll.

ODOSTOMIA CONSPICUA, Alder.

ODOSTOMIA UNIDENTATA, Mont. L. 3 mm. Hudl. Coll.

ODOSTOMIA UNIDENTATA, var. ELATA, Jeffr.

"Spire more elongated and base narrower." Brit. Mus.

ODOSTOMIA ALBELLA, Lov.

ODOSTOMIA MAGNA, Eth. and Bell. Pl. 2, fig. 15.

A slender, graceful shell; whorls 8–9, apex pointed, mouth a lengthened oval, with small and hardly perceptible tooth on upper part of the pillar. L. 10 mm. Mus. p. Geol.

ODOSTOMIA RISSOIDES, Hanl.

The estuarine clay in L. Larne is the only recorded locality in the British area for this shell. L. 1 mm.

ODOSTOMIA TURRITA, Hanl.

ODOSTOMIA STRIOLATA, Alder. Mus. p. Geol.

ODOSTOMIA INSCULPTA, Mont. L. 1·05 mm. Brit. Mus.

ODOSTOMIA SUBOBLONGA, Jeffr. L. 2 mm. Mus. p. Geol.

ODOSTOMIA WARRENII (?), Thomps. L. 1·75 mm. Hudl. Coll.

ODOSTOMIA EULIMÆFORMIS, Eth. and Bell. Pl. 2, fig. 14.

Shell long, narrow mouth, oval, pointed at base with strong tooth in centre of columella; whorls 4–5. L.

ODOSTOMIA OBELISCUS, Eth. and Bell.

Fusiform, smooth, glossy, solid, spire shortly tapering to an obtuse point, apex incurved, whorls 6–7, including a nucleus, smooth, flat, slightly compressed above; periphery strongly angulated, body whorl occupying three-fifths of the entire shell, suture narrow, aperture a long oval, outer lip expanded, contracting below; inner lip curved, forming a sharp angle at the base with the outer lip; tooth small, distinct, placed in front of and just above umbilical chink, which is deep and rather open. Under certain lights with a good lens there appears to be numerous fine spiral striæ beneath the glaze. L. 3·05 mm.

CHEMNITZIA PLICATULA, Broc. Mus. p. Geol.

CHEMNITZIA GRACILIS, Broc. (? *recta*, Eth. and Bell.). Warbn. Coll.

The broad, close-set, upright costæ define this species from any other, whorls long, elliptically convex, shell more acicular than *C. warringtoni*. L. (4 whorls only) 4 mm.

CHEMNITZIA WARRINGTONI, Eth. and Bell.

Whorls shorter and more convex than in *C. recta*,

ribs sinuous, interspaces equal in breadth to ribs. L. (7 whorls) 5½ mm.

CHEMNITZIA ACUTICOSTA, Jeffr.

Resembles *C. lactea*, but differs in shortness of spire and narrower ribs. L. 2 mm. Brit. Mus.

CHEMNITZIA EXIMIA, Jeffr. Brit. Mus.

CHEMNITZIA COSTELLATA (?), Grat. Brit. Mus.

Messrs. Wood and R. G. Bell thought this shell agreed with the description and figure of the type; without actual comparison, however, the ascription must be uncertain. The ribs are rather oblique, whorls 9–10, nucleus reversed, spiral, and inlocked.

Dolfuss says that it is not *Grateloups* shell. I consider it more like *C. lactea*, *L.*, in one of its forms. L. 6 mm.

CHEMNITZIA PUSILLA, Phil. Hudl. Coll.

CHEMNITZIA EUTERPE (?), Semp.

Whorls tumidly convex, with broad curved ribs; whorls to base, including ribs, crossed by fine, deeply impressed striæ. Only the mouth and adjacent whorls are known—mouth squarish, pillar straight, bearing on the upper portion, tracing a small obscure fold or tooth. Woodw. Mus.

CHEMNITZIA INTERSTINCTA, Mont. Brit. Mus.

CHEMNITZIA TENUISSIMA, Eth. and Bell.

A slender species with this name is in the Mus. p. Geol. It seems different to any species I know of.

CHEMNITZIA CLATHRATA, Jeffr. Brit. Mus.

EULIMELLA ACICULA, Phil.

ACLIS ELONGATA, Eth. and Bell.

Apex enlarged, stiliform, produced quadriform outer lip. It is not unlike *Pherusa gulsonæ*, but varies in the apex from this species.

NODOSTOMIA EULIMELLOIDES, Wood. Mus. p. Geol.

ODOSTOMIA (?) (RISSOA) SPIRALIS (CONICA), Eth. and Bell.

The shell does not quite agree with the recent species, and we formerly suggested a change of name. As there is some doubt, I now follow Messrs. K. and B. in their determination. Brit. Mus.

SCALARIA, sp. (?) PULCHELLA, Biv. See Phil. En. Moll., *sic.* t. x. fig. 1.

A small acute-spired shell, with flattish whorls, set with fine, narrow, close-set ribs. Unfortunately the only specimen was destroyed by an accident.

TURRITELLA PLANISPIRA, Wood.

The only example has less whorls and bands on it than in Mr. Wood's shell. Mr. Wood's shell does not agree with Nyst's fragment, pl. 38, fig. 9 (*Coq. foss. de Belg.*), and Mayer (*Journ. de Conch.*, v. 14, pl. 3, fig. 2) describes *T. sandbergeri*, Mayer, giving *T. planispira*, Wood, non-Nyst, as a synonym. For want of further evidence I retain Mr. Wood's name. L. 7, b. 2 mm. Brit. Mus.

TURRITELLA TRIPLICATA, Broc. (*Incrassata*, Sow). Pl. 1, figs. 14, 15.

One of the commonest shells of all, occurring from the fry to very large examples, exhibiting the changes from the prominent single carina of the young shell through all modifications to a nearly flat surface in the adult. These have received many names according to number of ridges; thus one ridge is *Subangulata*, Broc., two ridges *Bicarinata*, Eichw., three *Vermicularis*, Broc.; adult nearly flat, *Riepeli*, Partsch. L. 70, b. 20 mm. Brit. Mus.

HOMALOGYRA ATOMUS, Phil. Brit. Mus.

SKENEA PLANORBIS, Fabr. Brit. Mus.

JEFFREYSIA DIAPHANA, Alder. Brit. Mus.

JEFFREYSIA GLOBULARIS, Jeffr. Brit. Mus.

SOLARIUM CONULUS, Wienk. Brit. Mus. Pl. 2, fig. 16.

A fragment only showing the external markings in one place.

EULIMENE.

This is a difficult genus to deal with, and has received various names, *Littorina*, *Lacuna*, *Medoria*, *Paludestrina*, etc.; and except in extreme cases the shells run towards each other in the English crags. At St. Erth the examples are more definite, although variable, *E. terebellata* and *E.* (*lacuna*) *suboperta* showing colour. *E. terebellata* and its varieties are confined here to the more angular aud solid forms, *E. pendula* to those with rounded bases.

EULIMENE PENDULA, Wood. L. 11, b. 4½ mm. Brit. Mus.

EULIMENE PENDULA, var. TURGIDA, Eth. and Bell.

Short, whorls 6, apex acute, inner lip thin. Brit. Mus.

EULIMENE TEREBELLATA, Nyst.

The St. Erth shells are usually finer in texture, and less robust than those in the crags of east England; colour a foxy red. L. 8, b. 5 mm. Brit. Mus.

EULIMENE, var. CONICA, R. G. B. (MS.). Pl. 3, fig. 2.

Usually small, stunted, nearly always eroded at the apex. Woodw. Mus.

EULIMENE ACUMINATA, Eth. and Bell. Pl. 3, fig. 7.

Spire acute, with 7–8 flattened whorls, angulated in centre of body whorl; mouth oval, angular above, patulous below, slightly reflected on the pillar, obscuring a shallow groove behind; smooth, or finely striated under glaze, suture well defined. L. 10, b. 4½–5 mm. Warbn. Coll.

A large example in the collection of F. H. Harmer, Esq., F.G.S., when first exposed, was a deep rich red-brown colour, with bright yellow stripe round the base.

EULIMENE (?) BYTHINÆFORMIS, Eth. and Bell.

A round-mouthed shell resembling a Bythinia. The genus is doubtful.

HYDROBIA VENTROSA, Mont. Brit. Mus.

HYDROBIA ULVÆ, PENN. L. 5, b. 2 mm. Brit. Mus.

HYDROBIA COMPACTA, Jeffr. (*P. Z. S.*, 1884, pl. 9, fig. 9.)

Differs from *H. ulvæ* in its imperforate base, angular periphery, fewer whorls, and more solid pillar lip.

BARLEEIA.

A solitary example in the Hudl. Coll. may be referred to this genus with some probability.

RISSOA EHRENBERGII, Phil. Brit. Mus.

RISSOA MONTAGUI, Payr. L. 4, b. 2 mm. Brit. Mus.

RISSOA PARTIMCANCELLATA, Wood (MS.). Pl. 2, fig. 7.

Has three intercostal striæ on the lower part of body whorl, one on the penultimate; the upper part of each whorl is crossed by a single line; the striæ continue from periphery to base, but not above, as in *R. reticulata*. Not uncommon at St. Erth.

RISSOA BASI-SULCATA. Pl. 2, fig. 9.

A broad thick cone, with 5–6 rounded whorls, suture deep, ribs prominent erect, with finely striated interspaces, mouth broad expanded, varix on outer lip, pillar straight, expanding at base, with deep sulcus below periphery, extending from behind pillar round base of shell. L. 5, b. 3 mm. (Type) Mus. R. G. Soc., Cornw.

RISSOA RETICULATA, Mont. L. 3 mm. Brit. Mus.

RISSOA CURTA, Duj. (*intusstriata*, Eth. and Bell.). Pl. 2, fig. 8.

A solid and broad shell, with thick ribs, striated between. L.

RISSOA ENYSII, A. Bell. Pl. 2, fig. 12.

Conic, tapering to a blunt point, whorls 8, flatly convex, suture deep, ribs straight, ending at periphery

of body whorl, crossed by deep striæ continuing to base of shell, outer lip roundly lunate, inner lip slightly reflected in front of a minute perforation. L. 6, b. 3½ mm. (Type). Mus. R. G. Soc., Cornw.

RISSOA LANCIÆ, Calc.

I am indebted to M. Dolfuss for the determination of this species.

RISSOA FENESTRATA, Eth. and Bell. Warbn. Coll.

A turbinated, coarse-ribbed shell, with 3–4 large crossing striæ.

RISSOA SUBSTRIATA, Phil. L. 2½ mm. Brit. Mus.

RISSOA SEMISTRIATA, Mont. Brit. Mus.

RISSOA PULCHERRIMA, Eth. and Bell.

A small shell, with convex finely striated whorls crossed by gently swelling ribs, reaching rather below the periphery. Mus. p. Geol.

RISSOA GRACILICOSTATA, Eth. and Bell.

Smaller than *R. pulcherrima*, finely curved ribs, but no striæ. Mus. p. Geol.

RISSOA DENSECOSTATA, Eth. and Bell.

Finely curved and crowded, close-set ribs. Warbn. Coll.

RISSOA INCONSPICUA, Alder.

RISSOA OVALIS, R. G. Bell (MS.). Pl. 2, fig. 10. Brit. Mus.

Oval, shortly conic, smooth ; whorls slightly convex, body whorl large, suture slight, mouth lengthened, oval, outer lip simple, inner lip lightly enamelled. Brit. Mus.

RISSOA PENTADONTA, Wood (ii.). Pl. 2, fig. 13.

Smooth, conically ovate, spire short, apex blunt, whorls 6–7, mouth ovate to round, pillar lip well developed, inner lip furnished with five teeth, umbilical chink, well marked—marked with horizontal colour bands. L. 5 mm. Brit. Mus.

RISSOA PENTADONTA, var. PICTA, Eth. and Bell.
Colour bands as irregular perpendicular streaks. Brit. Mus.

RISSOA PENTADONTA, var. RIGIDA, Eth. and Bell.
Like the above, but without teeth, apex pointed, umbilicus slight, colour band on periphery. Brit. Mus.

RISSOA PARVA, Du Costa. L. 30·5, b. 2 mm. Brit. Mus.

RISSOA OBSCURA, Phil. En. Moll., sic. t. xxiii. fig. 10 (*R. obeliscus*, Eth. and Bell.), is probably our shell, and one of the vars. of *R. parva*. Striated and ribbed, the volutions are rather more swollen, and spire less acuminate than in our shell. Brit. Mus.

RISSOA MEMBRANACEA (?), A. Ad. L. 3·05 mm.
So named by the late R. G. Bell on the tablet in Brit. Mus.

RISSOA MEMBRANACEA, var. ELATA, Phil. Warbn. Coll.

RISSOA SOLUTA, Phil. (non-Jeffr. in Brit. Conch.) Brit. Mus.

RISSOA MILLETII, Eth. and Bell.
In shape like *soluta*, but larger and more swollen, covered with close-packed spiral lines round the whorls. Brit. Mus.

RISSOA CINGILLUS, Mont. L. 5½ mm. Brit. Mus.

RISSOA WHITLEYI, Eth. and Bell.
Strongly costulated and angulated; one example only. It may be the same as *R. clotho*, Hoernes, t. xlviii. fig. 20, which it closely resembles.

RISSOA (ONOBA) STRIATA, Ad.
The shells of this group of Rissoas are susceptible of considerable modification, as in

RISSOA (ONOBA) TRUNCATA, Eth. and Bell.
Shorter, stouter, and has a very oblique mouth; whorls 4, smooth, apex blunt. Brit. Mus.

RISSOA (ONOBA) CONULOIDEA, Eth. and Bell.

Broader than *truncata* and more conical. Brit. Mus.

(*Rissoa doliolum*, Phil., is very like the last two, except that it is ribbed.)

MENESTHO BASISTRIATA, Eth. and Bell.

A long and narrow shell; four whorls, body whorl very large, ridged from base to periphery; apex blunt, aperture narrow, inner lip nearly straight, outer lip a little expanded.

MENESTHO TRUNCATA, Eth. and Bell.

Short, broad, slight, narrow chink, mouth ovate. Warbn. Coll.

LITTORINA GIBBOSA, Eth. and Bell. Pl. 3, fig. 1. Mus. p. Geol.

LITTORINA CINCTA, Eth. and Bell.

A minute Littorina encircled with well-marked distinct striæ. Not *L. rudis*, var. *Jugosa*. Warbn. Coll.

LACUNA (? LITTORINA) SUBOPERTA, Son.

The shell seems to be more of a Littorina than a Lacuna. It is doubtful if it is the same as the crag species. L. 10, b. 6 mm. Woodw. Mus.

PHASIANELLA PULLUS, L.

CITHNA (?) TENELLÆFOMIS, Eth. and Bell.

Approaches *Cithna* (*Hela*) *tenella*, Jeffr. Warbn. Coll.

CITHNA FUSCA, Eth. and Bell.

Ovate, whorls 4, rounded, suture deep, apex blunt, inner lip straight, umbilicus obliquely curved, ending in deep perforation, enclosed by a well-defined ridge. Warbn. Coll.

TROCOCOCHLEA (OSOLINUS) ST. ERTHENSIS, Eth. and Bell.

May be distinguished from *T. turbinata* by the coarse muricated surface. Warbn. Coll.

TROCOCOCHLEA (OSOLINUS) LITTORALIS, Eth. and Bell. Pl. 2, fig. 18.

Shell conical, striated to upper whorls; whorls 6–7 flatly convex, aperture quadrate, pillar slightly swollen in centre, with shallow depression behind. Warbn. Coll.

TROCOCOCHLEA (OSOLINUS) TURBINATA, Born.

The only difference between the recent and fossil shells lies in the colouration, the recent shell being maculated, the fossil in flame-shaped lines. L. 15, b. 13 mm. Hudl. Coll.

TURBO (SENECTUS) NEWTONI, Eth. and Bell. (*Clanculus newtoni.*) Pl. 2, fig. 17.

Whorls marked with horizontal cords at top, middle, and base, with thin, prominent vertical plates between them; shell strongly turrited, with deep shoulders, suture well marked, base coarsely striated, umbilicus moderate, deep, mouth square. Mus. p. Geol.

TROCHUS (GIBBULA) MULTISTRIATUS, Wood.

Has a general resemblance to *T. patulus*, Broc., but wants the deep sutures. The flattened whorls 6–7 are impressed with deeply incised lines; slight projection on the inner lip; no umbilicus. L. 7, b. 10 mm. Brit. Mus.

TROCHUS (GIBBULA) UMBILICATUS, Mont. Mus. p. Geol.

TROCHUS (GIBBULA) ADANSONI (?) Payr.

"*Trochus* shaped like *T. adansoni*, strongly ridged and umbilicated." R. G. B., *in litt.* Woodw. Mus.

TROCHUS (CALLIOSTOMA) ZIZYPHINUS, L. L. 28, b. 25 mm. Brit. Mus.

TROCHUS (CALLIOSTOMA) ELENCHOIDES, Issel. (*T. Adriaticus*, var. K. and R. G. B.)

A long, flat-sided cone crossed by diagonal lines of growth, base of whorls angular; imperforate, strongly ridged below on under side of shell. Woodw. Mus.

TROCHUS (CALLIOSTOMA) BULLATUS, Phil.

In yellow clay; specimen destroyed in drying by falling to pieces.

TROCHUS (CALLIOSTOMA) NODULIFERENS, Wood.

The striæ are not quite so close as in the crag shell, and the rounded base is smooth, but in form and general character of sculpture there is no difference. (R. G. Bell, *in litt.*) Woodw. Mus.

Some imperfect shells seem to belong to the *T. granosus*, Wood, but require better specimens for accurate definition.

TROCHUS (CALLIOSTOMA) MILIARIS, Broc.

Jeffreys (*P. Z. S.*, 1883, p. 106) gives so many variations in this species, that the St. Erth shell doubtless belongs to it, although more strongly keeled than usual. L. 5, b. 6 mm. Mus. p. Geol.

CYCLOSTREMA NITENS, Phil. L. 1, b. 1 mm. Brit. Mus.

CYCLOSTREMA BASISTRIATA, Jeffr.

CYCLOSTREMA LÆVIS, Phil.

CYCLOSTREMA (TURBO) SPHÆROIDEA, Wood.

CALYPTREA CHINENSIS, L.

Not rare as adult; fry common. Diam. 1¼ inch. Brit. Mus.

CAPULUS HUNGARICUS, L.

A young specimen showing the first 2–3 involutions. Warbn. Coll.

SCUTUS BELLARDI, Michel. (See Hoernes, t. 1. fig. 23.) *Parmophorus minutus*, Eth. and Bell. Pl. 3, fig. 13.

A little shell which, except in size, so corresponds with Hoernes' figure, that it seems preferable to adopt the reference in place of the one given in the earlier list of St. Erth shells.

DENTALIUM (*minimum*, Eth. and Bell), sp.

Fragments of a tubular shell are not rare, and in one example a slight channel near the apex appears

to determine the genus. The name may stand till more perfect specimens are obtained.

CHITON DISCREPANS, Brown.

One plate, granulated on each side of a prominent ridge; granules few and small. Brit. Mus.

CHITON FASCICULARIS, (?) L. Brit. Mus.

The valves or plates are much worn, and are ascribed with some hesitation to the above forms.

UTRICULUS MAMMILLATUS, Phil. L. 1½ mm.

UTRICULUS TRUNCATULUS, Brong. L. 3 mm. Brit. Mus.

AMPHISPHYRA HYALINA, Turt. L. 1, b. 1 mm. Brit. Mus.

SCAPHANDER PUNCTATOSTRIATA, Migh. Pl. 3, fig. 12.

Less expanded in the aperture and smaller in size than *S. lignarius*. L. 9, b. 5–6 mm. Brit. Mus.

TORNATINA EXILIS, Eth. and Bell. Pl. 3, fig. 10.

Long, narrow; spire short, apex blunt, showing a little beyond body whorl. L. 2, b. 1 mm.

MELAMPUS (LEUCONIA) BIDENTATUS, Mont. (*Vide* Kendall and R. G. Bell.) Pl. 3, fig. 9.

The St. Erth shells are different from the type. The *M. fusiformis*, A. Bell, var. *elongatus*, Wood (*C. Moll.*, 2nd supplement), is, I believe, the St. Erth species. L. 12, b. 5 mm. Brit. Mus.

MELAMPUS PYRAMIDALIS, Sow. Pl. 3, fig. 8.

One example found by Sir. W. Warington Smyth. L. 16, b. 10 mm. Brit. Mus.

The presence of this shell at St. Erth led Messrs. Wood, Kendall, and R. G. Bell to correlate the deposit with the Walton crag. Similar shells, if not the same species (*Grateloup* and *Tournouer*), come from the French faluns, and from Italy.

PINGUICULA STRIATA, Phil. (*Beit. N. W. Deutschl.*, 1843, t. iv. fig. 23.)

A few shells corresponding (only smaller) to some Italian sub-appenine specimens compared with them, are all I have seen. The concentric impressed striæ on the body whorl easily distinguishes it from the following species as well as its form, which approaches the *R. ventricosa* of the Red Crag.

PINGUICULA SEARLESII, Eth. and Bell. Pl. 3, fig. 14. (*R. acuta*, K. and B. non-Phil.) *R. buccinea*, var. *minor*, *vide* Dolfuss.

This not uncommon shell does not agree with any species figured. It may be, as M. Dolfuss writes me, a minor form of *R. buccinea*, but it certainly differs from that type in the more tapering spire, smaller columellar tooth, the more pronounced tooth on the outer lip, and the greater spread of the enamel, and shallower canal. (R. G. Bell.) It does not agree with *R. acuta*, Phil., to which it was doubtfully assigned by K. and B. Shell thick, ovate slightly gibbous, whorls 5-6, smooth, inflated; outer lip thickened at the back; projecting tooth or swelling on the inner side; enamel wide, spread over body whorl; one fold or pillar upper tooth, produced by callous of thick enamel; lower projection of basal edge white, sometimes foxy-brown. The terms *minor* or *major* are not very satisfactory, and we have dedicated it to Mr. Searles V. Wood (ii.). L. 2-3, b. 2 mm. Brit. Mus.

PINGUICULA OVATA, Eth. and Bell. Pl. 3, fig. 15.

Body swollen, whorls 5, outer lip swollen inside, more so than in *R. buccinea*, the spire is longer, and upper canal longer; it appears to bring *R. searlesii* and *R. buccinea* together, but differs from either. L. 6½, b. 4 mm. Harm. Coll.

BIVALVES.

OSTREA, *var.* SINUOSA, Eth. and Bell. Pl. 3, fig. 16.

This variety is always flat and shallow, and almost circular in outline; the shell smooth, without fimbriations or costæ, or barely showing them beyond the concentric lines of growth. L. 60, b. 55 mm. (average). Brit. Mus.

OSTREA, *var.* SEMILÆVIS, Eth. and Bell. Pl. 3, fig. 17. A young shell.

This is a triangular pear-shape form, with pointed and deflected umbones, strongly ribbed on the lower, and partly so on the upper, valve. The figure is given to show the outline. L. 2½, b. 2 in. (average). Brit. Mus.

These are probably varieties of the common oyster, and usually exhibit signs of attachment on the upper part of the lower valve to an extraneous object, often to *Nassa semireticosa*. *O. edulis*, var. *sinuata*—Wood—resembles the former, but varies a little in the ornament and attachment.

OSTREA UNGULATA, Nyst.

A large lower valve, approaching a common form of *O. edulis*. L. 3½, b. 3 in. Brit. Mus.

OSTREA PLICATULA, Gmel.

The only valves I have seen of this and the preceding shells agree with the figures in the *Crag Mollusca*. They may be the same species. This is marked with strong rugose divergent ribs. Warbn. Coll.

PECTEN (JANIRA) MAXIMUS, L.

A few fragments are doubtfully referred to this species. Brit. Mus.

PECTEN OPERCULARIS, L. Brit. Mus.

PECTEN AUDOUNII, Payr. Warbn. Coll.

PECTEN BROCCHII, Eth. and Bell.

Figured in Brocchi's work as *plebeius*, Lam., in error. *P. audounii* may be an imbricated form of *P. opercularis*, and this a finely costated but not imbricated one. Brit. Mus.

PECTEN VARIUS, Warbn. Coll.

PECTEN PUSIO, L. Pl. 3, fig. 19.

R. G. Bell referred a coarsely imbricated piece to an aged example of this shell. Some other portions, including the figured example, have been obtained since. Brit. Mus.

PECTEN BRUEI, Payr. Warbn. Coll.

PECTEN CURVISTRIATA, Eth. and Bell. Pl. 3, fig. 18.

The fragment exhibits a portion of the shell ornamented with fairly closely-set straight ribs, crossed as well as interspaced by equi-distant curved erect squamæ. Hudl. Coll.

PECTEN DIVIGATA, Eth. and Bell. Pl. 3, fig. 20.

Another fragment, the ribs made up of 3–5 closely-set, smaller riblets, the interspaces rather wide, with shallow projections curving upwards and forwards, covered with fine perpendicular lines; other lines diverge vertically on each side of the ribs. Warbn. Coll.

The sculpture of these two forms is so unlike anything we can find, that it seemed desirable to give them a distinctive name.

PECTEN STRIATUS, Mull.

This is also a fragment, but agrees in ornamentation with Muller's species.

PECTUNCULUS PILOSUS, Lam. (*P. glycimeris*), L. Brit. Mus.

LIMOPSIS MINUTUS, Phil. Warbn. Coll.

NUCULA NUCLEUS, L. Brit. Mus.

NUCULA PROXIMA, Say. Pl. 3, fig. 21. Brit. Mus.

NUCULA SULCATA, Born. Brit. Mus.

CARDIUM TUBERCULATUM, L. Brit. Mus.

CARDIUM EDULE, L. (*C. semituberculatum*, Eth. and Bell).

The fragment is so large—l. 5¼, b. 5¾ centimetres—the umbonal area being lost also, that we felt unable to refer it to any living form. Some very large recent continental examples now in the British Museum enable us to refer it as above. Brit. Mus.

CARDIUM ECHINATUM, L. Brit. Mus.

CARDIUM ERINACEUM, Lam. (*C. deshayesii*, Eth. and Bell, in error.) Woodw. Mus.

CARDIUM HOERNESIANUM, Grat. (See Hoernes, t. 27, fig. 1.)

Several portions of a large cardium exactly corresponding to this species have been obtained. Both ribs and interspaces are quite smooth, except for the fine lines of growth. Brit. Mus.

CARDIUM PAPILLOSUM, Poli. Brit. Mus.

CARDIUM STRIGILLIFERUM, S. V. Wood. Brit. Mus.

CARDIUM MINIMUM, Phil.

CARDITA ACULEATA, Lam. Woodw. Mus.

A very fine example, with the two valves interlocked.

CARDITA CORBIS, Phil.

CARDITA STRIATULA, Eth. and Bell. Pl. 3, fig. 22.

Broader than long, posterior edge sloping, anterior rounded, apex acute. Shell marked with deep concentric striæ, margins crenulated.

ASTARTE McANDREWI, E. A. Smith.

Not dissimilar in outline to *A. triangularis*, but wants the crenellations on the ventral margins.

ASTARTE PARVULA, S. V. Wood.

WOODIA DIGITARIA, L. Brit. Mus.

LUCINA BOREALIS, L. Pl. 3, fig. 23.

The normal size of the adult St. Erth shell. Brit. Mus.

AXINUS FLEXUOSUS, Mont. Brit. Mus.

CYAMIUM MINUTUM, Fabr. Warbn. Coll.

BORNIA OVALIS, S. V. Wood. Pl. 3, fig. 24. (*Montacuta ellipsoides*, Eth. and Bell.)

This shell comes so near to the Crag form that we feel constrained to adopt Mr. Wood's name. The shell we named *M. ellipsoides* is in the British Museum; the figured example Mr. Warburton's. It is much larger than *M. bidentata*.

MONTACUTA BIDENTATA, Mont. Brit. Mus.

MONTACUTA OVATA, Jeffr. Pl. 3, fig. 25. L. 2½, b. 3 mm. Warbn. Coll.

MONTACUTA FERRUGINOSA, Mont. Brit. Mus.

MONTACUTA TRUNCATA, S. V. Wood.

The shell we collate with the Crag form slopes rather more on the posterior margin than the type, neither of them having the long produced sides of *M. ferruginosa*, of which, however, they may both be varieties. L. 4–7, b. 6–7 mm. Brit. Mus.

MONTACUTA PUSILLA, Eth. and Bell.

A thin, pellucid, squarely-oval shell, almost equilateral; umbones nearly central, elevated. *M. elliptica*, Jeffr., *P.Z.S.*, 1881, pl. 61, fig. 3, comes near to it; and so does Mr. Wood's figure in *Sup. Crag. Moll.*, t. x. fig. 21. It may be *Scintella transversa*, (Dollf. et Dauz., *Journ. de Conch.*, 1888, pl. 12, fig. 3). Miocene of Pontlevoy. L. 1, b. 1½ mm. Brit. Mus.

LASÆA RUBRA, Mont. Brit. Mus.

LASÆA PUMILA, S. V. Wood.

KELLIA ORBICULARIS, S. V. Wood. Brit. Mus.

KELLIA CORBULOIDES, Phil. Pl. 3, fig. 26 *a*, *b*, *c*. (*Alra trigonula*, Eth. and Bell.) Mus. p. Geol.

(I lately found a valve of this shell on Hayle Beach. As it was unrolled, and in the same condition as the other beach shells, it may be new to Britain. The occurrence is worth recording.)

LEPTON NITIDUM, Turt. Pl. 3, fig. 27. Brit. Mus.

VENUS OVATA, Penn. Brit. Mus.

VENUS MULTILAMELLA, Lam.

A fragment exhibiting the close-raised cross ribs. Warbn. Coll.

ARTEMIS EXOLETA, L. Pl. 3, fig. 28.

The hinge plate figured shows the absence of the large cardinal tooth. There are no signs of wear, fracture, damage, or disease to account for this. It is the only example known from St. Erth, and was found by the Rev. A. W. Mells. L. 50, b. 45 mm. Brit. Mus.

TAPES AUREUS, Gmel. Brit. Mus.

TAPES GEOGRAPHICUS, Chemn. (PULLASTRA, Mont.) Brit. Mus.

TAPES VIRGINEUS, L. Brit. Mus.

ERYCINA (SYNDOSMYA) LONGICALLIS (?), Phil.

A small shell we referred to this species with some hesitation, as the hinge line differed a little from the figure. Should larger examples be obtained, it may be found to be a new species.

MACTRA SOLIDA, L. Brit. Mus.

From an examination of the *Mactras* on Hayle beach, I am of opinion, with Dr. Jeffreys, that many of the Crag forms—such as *M. constricta*, *M. obtruncata*, *M. ovata*—are all decorticated varieties of this

shell, as a complete series of forms passing into each other may be observed. Brit. Mus.

MACTRA SUBTRUNCATA, Da. C.

THRACIA VILLOSIUSCULA, McGill. Brit. Mus.

MYA ARENARIA, L. Brit. Mus.

LUTRARIA ELLIPTICA, L. Warbn. Coll.

PETRICOLA LITHOPHAGA, RETZ. Warbn. Coll.

SAXICAVA RUGOSA, L. Warbn. Coll.

SOLEN ENSIS, L.

The groups of fossils are very unequal, the mollusca and foraminifera being the most abundant, and the ostracoda closely following them. Crustacea are scarce. A few species have been procured, plates and spines of three Echini, and several polyzoa. The rarity of these is due to the muddy nature of the soil. They are equally scarce in the estuarine clays of the N.E. of Ireland to my experience.

The very interesting discoveries of Holothurian and Tunicate bodies, and several Calcisponges—classes of object hitherto unknown in fossiliferous deposits, are due to the persevering and close research of Mr. P. F. Kendall, F.G.S.

A tooth of the Toper shark and some small vertebræ (? of pilchard) and a few gadoid otolites are the only traces of vertebrate animals.

PISCES.

GALEUS CANIS, and vertebræ and otolites undetermined.

CRUSTACEA.

PORTUNUS CORRUGATUS, Penn.

PORTUNUS HOLSATUS (?).

PORTUNUS PUSILLUS.

CARCINUS (MÆNAS).

MAIA SQUINADO, Latr.

GONOPLAX RHOMBOIDES, Fabr.

XANTHO FLORIDUS, Leach.

(All in Warbn. Coll.)

ENTOMOSTRACA, numerous, but not defined.

BALANUS, sp. (? *bisulcatus*).

ECHINODERMATA.

ECHINUS ESCULENTUS, L. Spines.

ECHINUS ETHERIDGEII, A. Bell.

Plates and spines of a small *Echinoid* are not uncommon. They do not correspond with any recent or fossil British species. The largest inter-ambulacral plates measure 4–4½ mm. in length, varying in breadth from ½ to 2 mm., bearing from 7 to 9; surrounded by small papillæ, on a finely granulated surface; ambulacral plates, 2 mm., with one primary and two secondary tubercles; pores in three pairs; spines deeply fluted; blunt; punctate; beaded on collar. The plates are not unlike those of a small *Miliaris*. All the plates seem to be of full growth. Not finding any species to correspond to it, I dedicate it, in remembrance of many kindly acts, to an old friend—R. Etheridge, Esq., F.R.S.

SPATANGUS PURPUREUS, Müll.

CUCUMARIA DUBIOSA, Herdm.

ANNELIDA.

POLYZOA.

CELLARIA CRASSA, S. V. W. (*C. sinuosa*, Hass.)

MELICERITA CHARLESWORTHII, M. Edw.

LEPRALIA PALLASIANA, *Moll.*

LEPRALIA (MICROPORELLA) VIOLACEA, Johnst.

HORNERA STRIATA, M. Edw.

PUSTULOPORA CLAVATA, Busk.

TUNICATA.

LEPTOCLINUM TENUE, Herdm.

SPONGIDÆ.

"Some (spicules) correspond in form and size with those of *Leuconia Johnstoni*, Cart., and others with *Leucandrea caminus*, Haeck." Dr. Hinde (in Kendall and Bell), who found others in the clay slightly different from any species with which he was acquainted.

CLIONA, sp.

ALCYONARIA, sp.

MELOBESIA.

1

2

3

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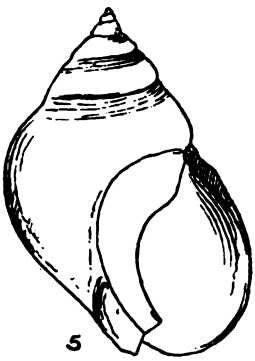
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a

b

c
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PLATE I.

		SPECIMEN IN
1.	*Columbella erythrostoma*, Bon. . . .	Mus. p. Geol. Lond.
2.	*Euthria corneus*, L.	Mus. R. Geo. Soc. Corn.
3.	*Murex rudis*, Bors.	,, ,,
4.	*Nassa mutabilis*, L.	,, ,,
5.	,, *St. Erthensis*, S. V. W. . .	Brit. Mus.
6.	,, *Solida*, S. V. W. . . .	,,
7.	,, *semireticosa*, E. and B. . . .	Mus. R. Geo. Soc. Corn.
8.	,, *recticostata*, Bell . . .	,, ,,
9.	*Lachesis multistriata*, E. and B. . .	Brit. Mus.
10.	*Pleurotoma Cornishii*, E. and B. . .	Mus. R. Geo. Soc. Corn.
11.	*Nassa sulcata*, E. and B. . . .	,, ,,
12.	*Cerithium variculosum*, S. V. W. . .	Warb. Coll.
13.	,, *reticulatum var. trinodosa*, E. and B.	Mus. R. Geo. Soc. Corn.
14, 15.	*Turritella incrassata*, Sow. . .	,, ,,

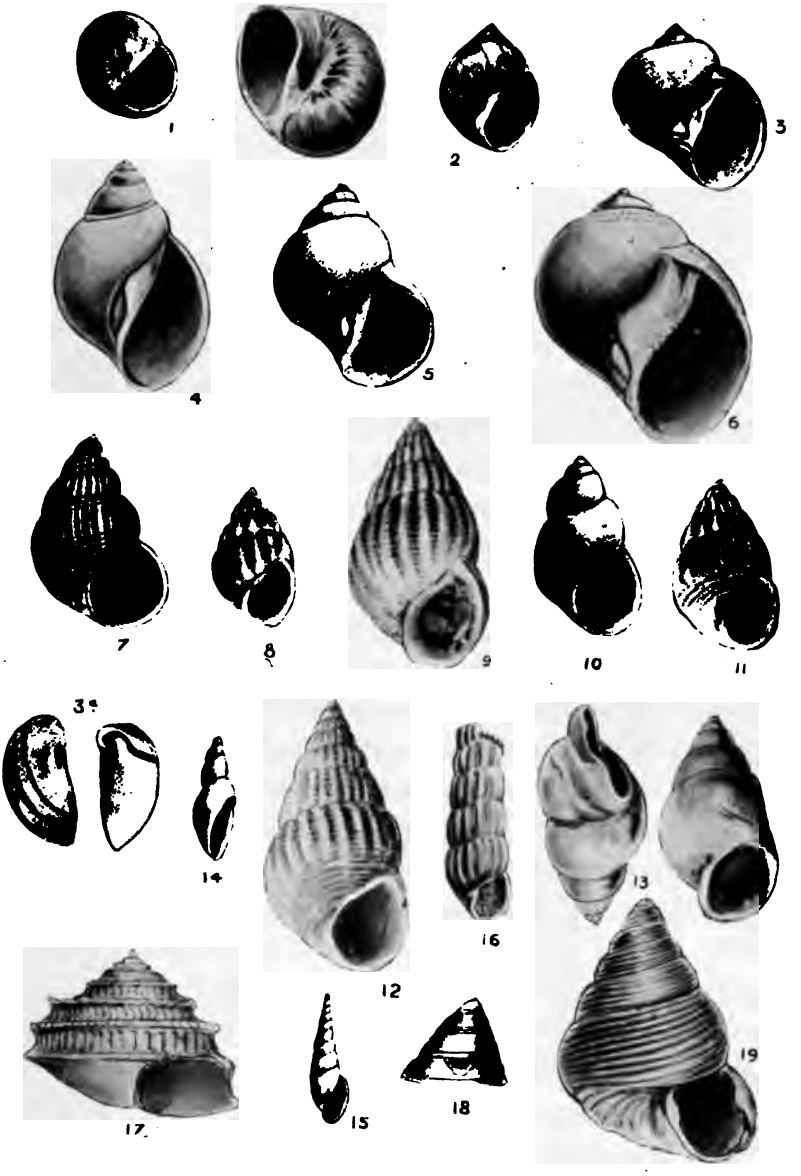
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PLATE II.

		SPECIMEN IN
1.	*Natica millepunctata*, Lam. . . .	Mus. R. Geo. Soc. Corn.
2.	,, *sordida*, Phil. . . .	,, ,,
3.	,, *consors*, S. V. W. . . .	Brit. Mus.
3a.	,, ,, (*operculum*) . . .	Warb. Coll.
4.	,, *Warburtoni*, E. and B. . .	,,
5.	,, *varians*, Duj.	
6.	,, *catenoides*, S. V. W. . . .	Brit. Mus.
7.	*Rissoa lanciæ*, Calc. . . .	Mus. R. Geo. Soc. Corn.
8.	,, *curta*, Duj.	
9.	,, *basisulcata*, E. and B. . .	,, ,,
10.	,, *ovalis*, R. G. B. . . .	Warb. Coll.
11.	,, *montagui*, Payr. . . .	Mus. R. Geo. Soc. Corn.
12.	,, *Enysii*, E. and B. . . .	,, ,,
13	,, *pentadonta*, S. V. W. (II.) . .	,, ,,
14.	*Odostomia eulimaeformis*, E. and B.	
15.	,, *magna*, E. and B. . . .	Warb. Coll.
16.	*Chemnitzia gracilis* (?), Broc (?)	
17.	*Turbo Newtoni*	Mus. P. Geo.
18.	*Solarium conulus*, Weink. . . .	Brit. Mus.
19.	*Trococochlea St. Erthensis*, E. and B. .	Warb. Coll.

R. lanciæ and *R. partimcancellata* in lists are probably the same species.

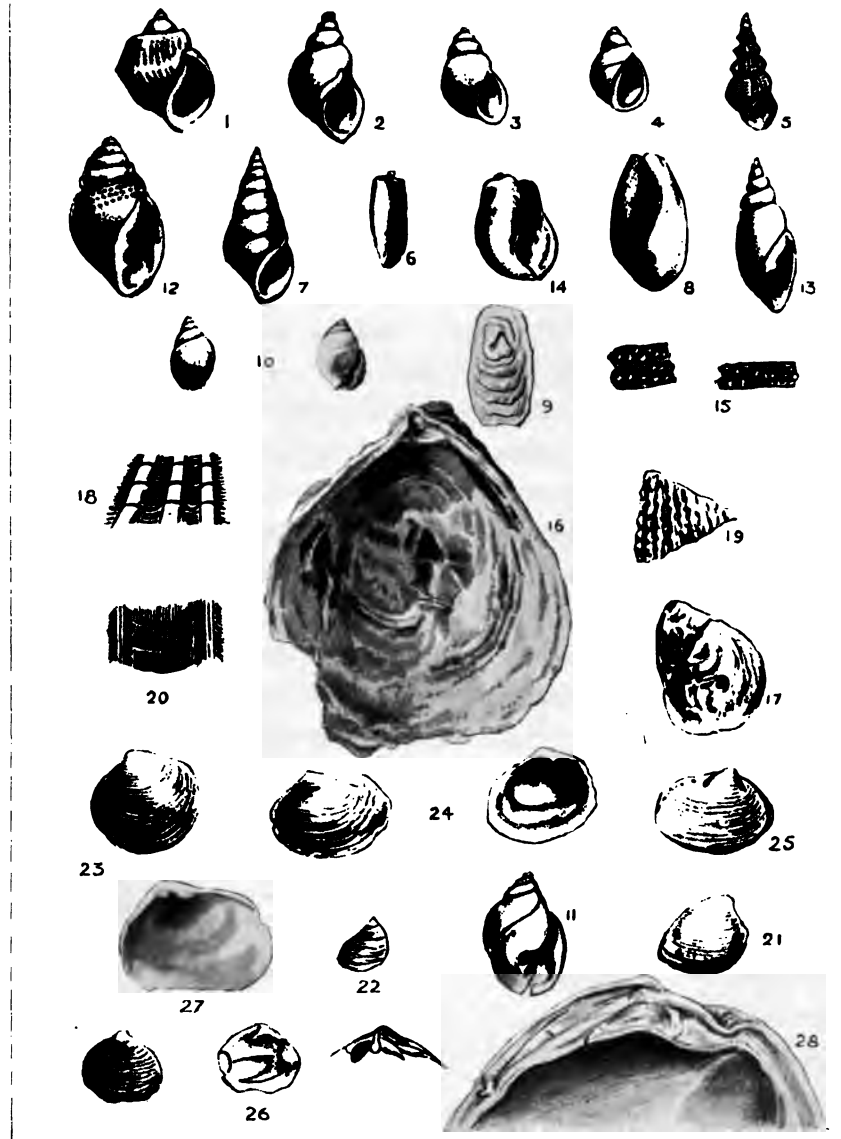
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PLATE III.

		SPECIMEN IN
1.	*Littorina Gibbosa*, E. and B.	
2.	*Eulimene var. conica*, E. and B.	
3.	*Lacuna suboperta.*	
4.	*Cithna tenellaeformis*, E. and B.	
5.	*Rissoa Whitleyi* (? *Clotho*, *Hornes*), E. and B.	
6.	*Tornatina exilis*, E. and B.	
7.	*Eulimene acuminata*, E. and B.	
8.	*Scaphander punctato striata*, Migh. . .	Brit. Mus.
9.	*Scutum Bellardi* (?)	
10.	*Ringicula Searlesii*, E. and B. . . .	Mus. R. Geo. Soc. Corn.
11.	,, *ovata*, E. and B . . .	Harm. Coll.
12.	*Melampus pyramidalis*, S. V. W. . .	Brit. Mus.
13.	,, *fusiformis*, A. Bell . . .	Warb. Coll.
14.	*Amphisphyra hyalina*, Turt.	
15.	*Echinus Etheridgei*, A. B. . . .	Mus. R. Geo. Soc. Corn.
16.	*Ostrea edulis var. sinuata*, S. V. W. . .	,, ,,
17.	,, *var. semilaevis*, E. and B. . .	,, ,,
18.	*Pecten curvistriata*, E. and B. . . .	Hudl. Coll.
19.	,, *pusio*, L.	Mus. R. Geo. Soc. Corn.
20.	,, *divigata*, E. and B. . . .	Warb. Coll.
21.	*Nucula proxima*, Scy. . . .	Mus. R. Geo. Soc. Corn.
22.	*Cardita striatula*, E. and B.	
23.	*Lucina borealis*, L.	,, ,,
24.	*Bornia ovalis*, S. V. W. . . .	Warb. Coll.
25.	*Montacuta ovata*, Jeff. . . .	Warb. Coll.
26, a, b, c.	*Kellia corbuloides*, Phil. . .	Mus. Prac. Geol.
27.	*Lepton nitidum*, Turt. . . .	Mus. R. Geo. Soc. Corn.
28.	*Hinge line of Artemis exoleta*, L. . .	Brit. Mus.

ON THE PROBABLE CAUSES OF THE SEEMING ABSENCE OF PALÆOLITHIC MAN FROM CORNWALL.

By Alex. Somervail,
Torquay.

(Read November 9th, 1897.)

It almost amounts to a paradox that the county of Cornwall should as yet have yielded no trace whatever of Palæolithic man, seeing that in the immediately adjoining county of Devon the wealth of his existence is so profusely scattered about.

This seeming paradox is also heightened by the fact that Cornwall has also up to the present time afforded not a single example of any of the numerous extinct animals with which man was associated in the sister county, the abundance of which animal remains is equally striking.

There must consequently be some strong, efficient, and very general reason, or reasons, for this entire absence of the proofs of Palæolithic man, and the animals who were his contemporaries, from one area so closely connected with that of another, where the evidences of the existence of both are so greatly abundant.

One very obvious reason in explanation of this

might be urged, is the absence of the massive beds of limestone from Cornwall, which are so characteristic of Devonshire, and which so abound in caves as to have afforded a shelter for both man and animals, where their remains are principally preserved. It might still further be urged that, not only is it due to the absence of caves, but also to the paucity of limestone itself in Cornwall, where the soil in many districts is so hungry for lime that the bones of man and animals had no chance of preservation.

Such reasons, however good and true, in certain respects do not in the least degree explain the entire absence of the stone implements used by Palæolithic man, which implements are in themselves absolutely imperishable, and are in themselves a necessary, and frequently the only tangible proofs of his existence. We are, therefore, compelled to seek for some more efficient cause than the mere absence of thickly-bedded limestones, or the poverty of calcareous matter in those deposits where otherwise we might reasonably have expected the remains of the extinct animals and man to have been preserved.

This cause I believe to be due to the present natural configuration of the county of Cornwall, which immediately to the south-west of Devonshire is a long, narrow, and somewhat highly elevated ridge in the direction of its longer axis.

During that portion of the Pleistocene period, when Palæolithic man and the extinct mammalia

were inhabitants of the adjoining broader stretches of the lower-lying flat lands in Devonshire and the south of England, the land which now forms the Cornish peninsula had undoubtedly a much higher elevation than now.

This is a fact almost universally acknowledged among geologists, and seems to rest on proofs of an unimpeachable nature.

This greater elevation of the land during the Pleistocene epoch is generally admitted to have been more than 1000 feet above its present level.

The late Mr. Godwin Austen[1] has—irrespective of any special theory—most conclusively shown that the former coast-line during this period of time must have reached as far out to sea as the present sounding line of 200 fathoms. His views on this subject have been endorsed by Lyell, Prestwich, and by others as a correct induction from observed facts.

The difference, therefore, between the present and the past sea levels, or between the coast-line of to-day and that of the Pleistocene period, would mean that the land then stood 1200 feet higher than now.

Reducing this estimate to the round number of 1000 feet, its effect would be to lay bare a most extensive tract of low-lying land — now

[1] *Quar. Jour. Geo. Soc.*, vol. vi. p. 29, and other papers in same journal.

forming the sea bottom—extending out to sea far beyond the Scilly Isles.

This same elevation would also produce in the presently exposed land surface of Cornwall a highly elevated, long, narrow, and steep-sided ridge, apt to be swept by melting snows, torrential streams and rains, which would hurry and carry to the lower levels anything within their power of conveyance.

Such may, therefore, be regarded as a reasonably fair estimate of the physical conditions of Cornwall prevailing during the Pleistocene period. If we even very considerably reduce the elevation already given the conditions still hold good.

My contention, then, is this. The present exposed surface of the county of Cornwall, with its much higher elevation during the middle and late Pleistocene periods, was, for the greater part, a region destitute of those forests which flourished on the plains and gave shelter and food to the extinct mammalia. That these animals and Palæolithic man himself were present on the lower grounds we cannot for a moment doubt. These plains, however, where both were present, and where man no doubt hunted these wild animals, as he did in other parts of England, are now below the waters of the sea.

Devonshire, but for its numerous limestone caves, scarcely affords us any record of Palæolithic man whatever, with the few exceptions of

a few of his implements obtained from the extreme east of the county, which have been found in the valley of the river Axe,[1] where the land is beginning to lose its narrow ridge-like form and to broaden out into more expansive plains.

This flatter and more extensive surface contour, although devoid of limestone caves, has, nevertheless, yielded abundance of remains of the extinct animals, and also the tools made use of by Palæolithic man. The explanation of this being, I think, the much less torrentially-swept drainage of the less steep contour of the various areas where they have been found.

Among such areas entirely devoid of limestone caves are those in the counties of Wilts, Hampshire, Kent, Middlesex, Essex, Surrey, Oxford, Cambridge, Suffolk, Norfolk, etc., which in numerous localities have yielded evidence of both men and animals.

All of these areas lie in counties geographically favoured for the preservation of such remains by the nature of their drainage, the rivers of which debouch on plains which have arrested their lighter and more loamy contents. It is, indeed, from sources of this kind—rather than from the limestone areas possessing caves—that the more important and completer evidences have been furnished relating to the occupancy of our country by Palæolithic man and the animals associated with him.

[1] EVANS, *Ancient Stone Implements*, p. 559.

It is, then, to these two sets of conditions, viz., the geographical configuration of the county and the non-existence of limestone caves, that up to the present time no trace of these ancient men and animals, who were once doubtless present in Cornwall, have as yet been detected.

If such remains are in the future to be discovered they must be looked for in the upper portions of those coarse detrital deposits underlying the beds of the age of those containing the human skulls, as have been found in the Pentuan valley.

These coarse detrital tin deposits, especially their upper deposits, and whatever may have been removed from them by denudation before the accumulation of the beds above them—marking the advent of Neolithic man and a new set of physical as well as of vital conditions—I regard as the equivalents of the breccia of Kent's cave, and the high-level river gravels occurring in the counties before mentioned.

The deposits forming the tin ground are, therefore, the Pleistocene waste of the narrow and once elevated ridge of land which now forms the Cornwall of to-day, from which was cleanly swept the *débris* belonging to that epoch. This *débris* will naturally fine out as it recedes from its source of origin and spreads seaward towards the old Pleistocene lands, over which we cannot for a moment doubt both men and animals were present.

A lucky find in the tin ground, or a chance haul of the fishing trawl, may some day suddenly reveal that tangible evidence to our eyes, or senses, which our minds are already convinced of, viz., that both Palæolithic man and the extinct animals were occupants of Pleistocene Cornwall.

ADDITIONS TO THE LIST OF FORAMINIFERA FROM THE ST. ERTH CLAY.

By Fortescue William Millett.

(Read November 9th, 1897.)

That the interest excited by the St. Erth deposit is unabated is shown by the number of applications for further information respecting the organic contents; consequently it may be of advantage to take this opportunity of making a further addition to the list of species of foraminifera as yet determined, rather than wait for the completion of the work.

The microzoa are by no means equally distributed throughout the St. Erth clay; not only is there a variation in the relative abundance of the different species in various portions of the bed, but some species seem to be confined to localities very limited in extent, and it will not be possible to make a complete list until samples from all portions of the bed have been examined.

Of the eighteen varieties now added, one is new to science, and four are for the first time recorded as fossil.

Of these forms the following require particular notice:—

Miliolina rotunda, d'Orbigny, sp. This species,

× 135

LAGENA ORBIGNYANA, *var.* calcar, Millett.

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distinguished from *M. seminulum* by its inflated chambers and large circular aperture, is found living in the Mediterranean, and is common in the shallow water of the Malay archipelago. It is the largest of the St. Erth *Miliolinæ*, and has not heretofore been recorded as a fossil.

Bulimina subteres, Brady. Its distribution in the living state is world-wide. Fornasini records it from the pliocene of Ponticello di Savena, near Bologna, Italy.

Lagena Orbignyana, var. *Wallerina*, Wright. Known hitherto only from the south-west of Ireland, at depths of over fifty fathoms. In most of the St. Erth specimens the central boss is resolved into a ring of corresponding size.

Lagena Orbignyana, var. *calcar*, nov. var. Differs from the type in having a set of radial spines on the aboral portion of the peripheral carina. Length, 0·24 mm.

Dimorphina tuberosa, d'Orbigny, var. Differs from the type in having a linear aperture.

Discorbina excavata, Terquem, sp. This is a *Discorbina* of the *obtusa* type. Found on the coast of Dunquerque by Terquem, and at Jersey by Halkyard. Not hitherto recorded fossil.

ADDITIONAL LIST OF FORAMINIFERA FROM THE ST. ERTH CLAY.

Miliolina rotunda, *d'Orb.*, sp. Rather rare.
Bulimina subteres, *Brady*. Very rare.
Lagena Orbignyana, *var.* Wallerina, *Wright*. Rather rare.
„ „ *var.* calcar, *nov. var.* Rather rare.

Lagena recticulata, *Macgillivray*. Frequent.
Polymorphina regina, *B. P. and J.* Very rare.
Dimorphina compacta, *B. P. and J.* Rather rare.
„ tuberosa, *d'Orb., var.* Very rare.
Globigerina inflata, *d'Orb.* Very rare.
Pullenia obliqueloculata, *P. and J.* Very rare.
Discorbina araucana, *d'Orb., sp.* Rather rare.
„ lingulata, *Burrows and Holland.* Frequent.
„ excavata, *Terquem, sp.* Very rare.
Truncatulina Aknerĭana, *d'Orb., sp.* Rather rare.
„ refulgens, *Montfort, sp.* Very rare.
Pulvinulina crassa, *d'Orb., sp.* Very rare.
„ canariensis, *d'Orb., sp.* Very rare.
Rotalia orbicularis, *d'Orb.* Very rare.

ON A NODULE OF FLINT CONTAINING LIQUID.

By Howard Fox, F.G.S.

(Read November 9th, 1897.)

Last June the son of Mr. W. H. Daniell, of Falmouth, picked up a flint nodule about the shape of a small orange, at Lee, on the Solent. The lad was only four years of age, and found it on the foreshore, left dry by the ebb tide. He discovered that by shaking it he could hear liquid inside. Mr. Daniell lent me the nodule, which I sent to Dr. Hinde, F.R.S., who informs me that he never met with a similar case before. He wrote as follows :—

"The presence of liquid in the central hollow, though very unusual in the case of these nodules, is more a matter of curiosity than of special scientific interest. Many hollows in flints are lined with a layer of small quartz crystals, which must have been deposited from a solution, thus indicating that the cavity must at one time have contained liquid."

On September 24th last Dr. Hinde again wrote to me from Croydon, as follows :—

"I came across a rounded flint when out for a walk last Sunday, containing a loose solid body in the interior, which can be distinguished when the stone is shaken. I think in your specimen there is

a similar loose solid present in the interior, as well as the fluid.

"I have made inquiries of Mr. H. B. Woodward, F.R.S., and of others acquainted with our chalk flints, and cannot hear of any nodule containing liquid having been observed. H. B. W. called my attention to a note in S. Woodward's *Geology of Norfolk*, 1833, p. 36, in which these stones are referred to as Ætites, 'spherical pebbles having a nucleus originating in a sponge; these are sometimes loose, the pebbles are then called "Eagle Stones."' H. B. Woodward quotes this in the *Geological Survey Memoir of the Country round Norwich*, 1881, p. 28, and adds that the term Ætites was given by Pliny. Near Norwich these stones occur in the flint gravel derived from the chalk."

Mrs. Daniell values her son's discovery too highly to part with it, but I gladly present to your Museum the nodule containing a loose solid body, which Dr. Hinde found and describes above.

NOTE.—Since the foregoing was written, my friend Mr. W. A. Fawcus, of Menhay, near Falmouth, writes to me as follows:—

"On the beach at Seaton Carew, in the Sixties, were banks of shingle containing large quantities of black and white flints. The piece in question was about six inches long, and about three inches broad, with black edges. At one end was a white nodule, the size of a hen's egg. On throwing the piece against a rock I distinctly remember being surprised that the nodule smashed and bespattered the face of the rock with a thick, white, creamy liquid, the consistency of the lime-wash I use for marking the tennis ground."

NOTES ON VERYAN AND OTHER LIMESTONES ASSOCIATED WITH RADIOLARIAN CHERTS IN SOUTH CORNWALL.

By Howard Fox, F.G.S.,

With Notes and Sketches by Dr. G. J. Hinde, F.R.S.

(Read November 9th, 1897.)

In the first volume of the *Transactions* of your Society (pp. 107–113) an interesting paper appears by the Rev. S. I. Trist, "On the Limestone Rocks in the Parish of Veryan." It is accompanied by a map showing the general direction of these beds. The succeeding paper in the same volume is by Canon Rogers, entitled "Observations on the Limestone of Veryan and the Neighbouring Parishes." Subsequent volumes contain references to these beds by Dr. Boase,[1] Rev. D. Williams,[2] C. W. Peach,[3] I. H. Collins,[4] and myself.[5] Elsewhere Sir Henry De La Beche[6] refers to them, as does Prof. Sedgwick[7] in his paper on "The Slate Rocks of Devon and Cornwall." Suffice it to say here that these limestone beds are generally found

[1] Vol. iv. pp. 266–8.
[2] Vol. vi. p. 336.
[3] Vol. vi. pp. 51–8, vol. ix. pp. 55–6.
[4] Vol. x. pp. 5, 52.
[5] Vol. xii. pp. 39–57.
[6] *Rep. Geol. of Corn., Devon, and W. Som.*, pp. 85, 146–7.
[7] *Q.J.G.S.*, vol. viii.

alternating with shales and radiolarian cherts, and are apparently overlaid by Caradoc quartzites.

As none of these limestone beds appear to have been examined microscopically, I asked Dr. Hinde, F.R.S., whether he would be so kind as to give me a report on them. To this he readily assented. He both sliced and examined a large number of specimens which I sent him from various localities in the parishes of Veryan, St. Michael Caerhays, St. Goran, and Creed, as well as from Nelly's Cove in the parish of St. Keverne and from Mullion Island. The specimens from St. Goran, Creed, and Mullion Island proved to be either crystalline or devoid of organic structure. The accompanying notes by Dr. Hinde describe the rock slices which show organic structure, and his sketches [see plate] represent some small tubes of uncertain origin, which characterize some of the beds from the other localities. Dr. Hinde writes to me as follows: "I am afraid the geological age of this rock cannot be found out from sections of it. The small tubes, of which I send some camera sketches drawn to the same scale, are insufficient for the purpose, since we do not definitely know what they belong to, and even if they are Pteropods we are not much nearer a determination. There are somewhat similar tubes in sections of Cambrian limestones from the Wrekin and in the Middle Devonian rocks of North America. For the proof of their geological horizon we must trust to finding more hopeful specimens in future."

NOTES ON LIMESTONES FROM THE VERYAN DISTRICT, CORNWALL.

1. *Gwendra Hill.*—The specimens examined are from ¾ mile east of Pendower House, and from the east hedge at 50, 80, and 100 yards from the foot of the hill. The rocks are dark bluish, fine-grained limestones, traversed by veins of calcite. Under the microscope thin sections have a dirty, flecked appearance with, in some instances, tubes, referred to below; in others, obscure indications of doubtful organisms. The sections from the different localities are very similar to each other, and they might have been derived from the same bed of rock.

2. *Pendower Beach.*—A compact, bluish, fine-grained limestone, having the same general appearance under the microscope as the rock from Gwendra Hill. The fossil traces are obscure. In addition to the small tubes there are fragments of echinoderms, probably crinoidal.

3. *Foreshore between Pendower Beach and Gidley Well.*—Compact, bluish limestone, with veins and numerous fine threads of calcite. The rock is mainly composed of echinodermal (= crinoidal) fragments, and the small tubes are present, though rarely.

4. *Foreshore between Gidley Well and Caradoc Quartzite Region.*—Dark bluish limestone, with veins of calcite. Under the microscope the sections have a flecked appearance, as in the Gwendra

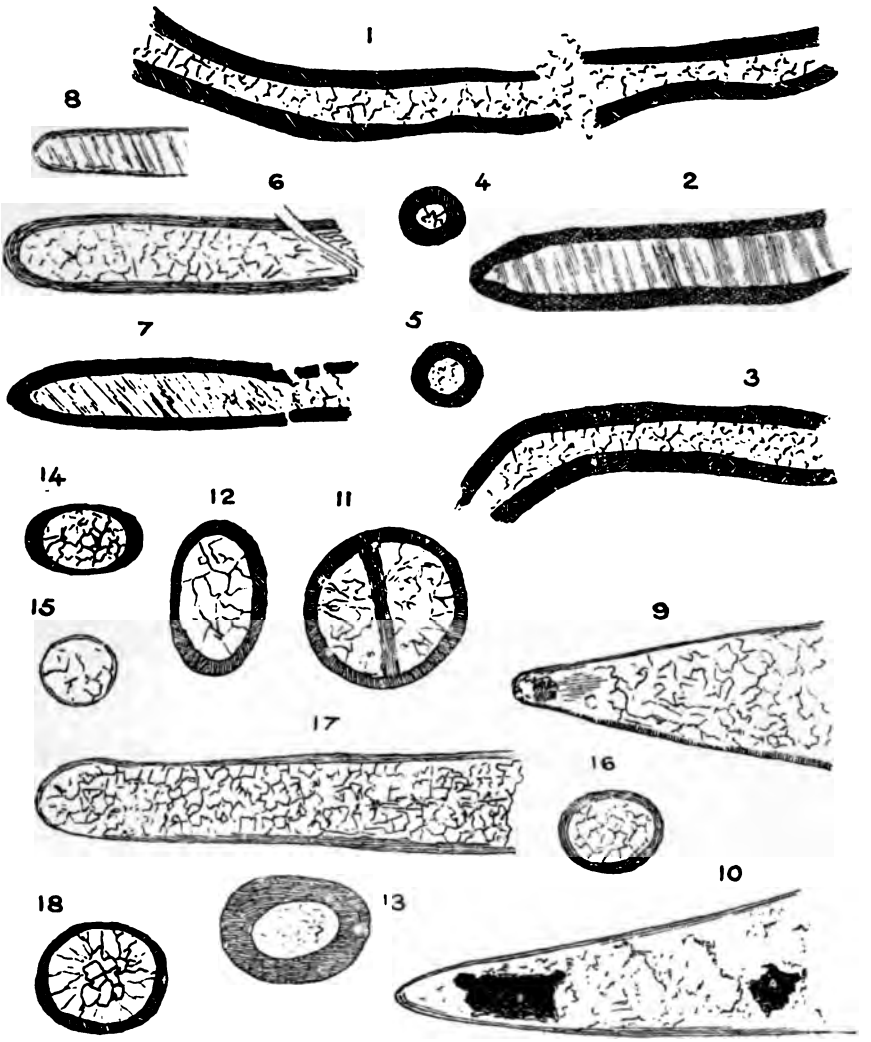
Hill rock. No crinoidal structures recognizable, and the small tubes but rarely shown.

5. *Cliff at Paradoe Cove.*—Compact, grey to dark limestones, with some grit. Some coarser grained, with pyrites. In one section the dark rock is mainly of quartz grains in a limestone matrix. Another section of a dark compact limestone is seen to consist chiefly of crinoidal remains in a very fine granular limestone matrix. The rocks from this locality differ very considerably from those previously mentioned; no tubes were recognized in the sections.

6. *Polcouta.*—Compact, dark bluish limestone. Under the microscope the sections are precisely similar to those from Gwendra Hill.

7. *Polgrain Hill.*—Specimens from east hedge of road 40 yards down: from massive beds at top of hill, and from the west hedge. The limestone is bluish, compact, and in thin sections, has the same microscopic appearance as the Gwendra Hill rock, but the tubes are shown much more distinctly, and the rock appears to be mainly composed of them.

8. *Nelly's Cove (Porthalla).*—A bluish grey, compact, close-grained rock, less crystalline than the Veryan limestones. Thin sections under the microscope contained crinoidal structures and linear sections of fossils, which may possibly be Trilobites; but of this I am not certain. The greater part of the rock is a finely granular limestone, without recognizable fossils. It is in character very distinct from the Veryan limestones.



MICROSCOPIC TUBES IN VERYAN LIMESTONES.

Figures 1, 2, 3.—Longitudinal sections of tubes with relatively thick walls (form *a*). The tubes are now infilled with calcite. Enlarged 100 diameters. From Gwendra Hill and Polgrain.

Figures 4, 5. Transverse sections of the same. × 100. Polgrain.

Figures 6, 7, 8.—Longitudinal sections of straight, nearly cylindrical tubes (form *b*); now infilled with calcite. × 100. From Gwendra Hill, Gidley Well, and Polcouta.

Figures 9, 10.—Sections of openly conical tubes with thin walls (form *c*). × 100. Polgrain.

Figures 11, 12, 13, 14, 15, 16.—Transverse sections of tubes of various sizes and thickness of wall. × 100. Polgrain, Pendower Beach, Gidley Well.

Figures 17, 18.—Longitudinal and transverse section of *Styliola fissurella*, Hall, a Pteropod from the Middle Devonian of Eighteen-mile Creek, near Buffalo, New York. × 100. For comparison with the tubes figured above. Infilled with calcite.

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NOTES ON THE SMALL TUBES IN THE VERYAN LIMESTONES.

It has been already mentioned that the Polgrain limestones contain numerous microscopical tubes, and they also occur, though rarely or less readily recognizable, in the limestones from Gwendra Hill, Pendower Beach, those on the foreshores further eastwards, and again in the limestones from Polcouta. The tubes are only recognizable in thin transparent sections under the microscope. They are sub-cylindrical or openly conical hollow tubes, straight or curved, without longitudinal or transverse partitions, and the walls are apparently smooth within and without. The tubes terminate obtusely, without any inflation, and they are open above without indications of a lid or operculum. Transverse sections of the tubes are circular or oval, more frequently the latter; but this may arise from being cut obliquely. The tubes range from ·22 mm. to ·93 mm. in length and from ·06 mm. to ·19 in width.

There are two or three varieties of the tubes present in these rocks. One form (*a*) is usually somewhat curved, sub-cylindrical, with the walls relatively thick. The form appears to be the commonest. Another form (*b*) closely allied is straight, with less robust walls than in *a*. In a third form (*c*) the tube is openly conical, gradually widening from the base to the summit, and the walls are very slender, contrasting greatly with those of the form *a*.

The real nature of these tubes is uncertain. In form and size they somewhat resemble examples of *Styliola*—a genus of pteropod mollusca represented in Silurian and Devonian rocks in North America and in Bohemia. I have also seen very similar tubes in sections of Cambrian limestone (*Paradoxides* beds) from the Wrekin, Shropshire.

The only other recognizable fossil structures in the Veryan limestones (which I have examined) are fragments of crinoids. Unfortunately the fossil evidence is at present inadequate to determine their geological horizon.

Royal Geological Society of Cornwall.

THE EIGHTY-FIFTH

ANNUAL REPORT

ETC., ETC.

PENZANCE

1899.

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R. T. Hall (formerly of the Cape Copper Mines), Africa.
William Hollow (formerly Manager of the Providence Mines), Leyton, Essex.
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Stephen Thomas.

The Secretary requests the favour of his being informed of any inaccuracies in the foregoing lists.

THE

ANNIVERSARY ADDRESS OF THE PRESIDENT,

JOHN DAVIES ENYS, Esq., F.G.S.,

To the General Meeting, November 8th, 1898.

Ladies and Gentlemen,—My first duty is, for the second time, to present Mr. J. H. Collins with one of the two gold medals given by a Cornish society to its members. In 1893 I presented Mr. J. H. Collins with the gold medal founded by Mr. J. Henwood to be given by the Royal Institution once in three years to the author of the best paper published in their journals. It has now fallen to my lot to present Mr. J. H. Collins with the gold medal founded by William Bolitho to be given to a member of this Society. I shall not enter into any account of Mr. J. H. Collins' work, but will quote the fact that the *Bibliotheca Cornubiensis* gives Mr. Collins the credit for over forty papers or books. This number can be now greatly increased. It is not by number of works that a man ought to be judged, but by their value, and I may say that Mr. Collins need not fear this test. Mr. Collins' papers extend over a great number of subjects, and refer to other counties besides Cornwall, with which he has been so long connected.

I have thought it worth while to put together such records of the submarine forest which have been from time to time published in works on Cornwall, both historical and geological, and hope that they may prove of interest to the meeting. I have quoted authorities to show that the shores of Pembrokeshire have similar traces of submarine forests. I have also quoted some instances of the denudations of the coast, to show that

in some places the coast has risen, in others sunk, and, thirdly, parts have been destroyed.

Sir Henry de la Beche.—Traces of submerged forest extend from near Lyme Regis to Bridgwater in various places round the whole coast—for instance, at Torbay, Millardreth near Looe, Hayle, Perran Porth, St. Columb Porth, Taw and Torridge, Bideford, and Porlock.

From a work on *East and West Looe* by Thomas Bond, 1823, p. 98: "At a beach called Millardreath (mill on the sands), about a mile to the eastward of Looe, when the sand is much lowered by heavy seas, peat and trunks of trees are exposed, as I have myself seen. This timber is much decayed, and is of a red colour." He quotes from a Scawen MS. as to timber visible at a league from the shore between Rame and Looe, of which he could get no confirmation.

W. C. Borlase (*Archæologia*, vol. xliv.) mentions the denudation of the Cornish cliffs near Newquay; several tumuli have fallen into the sea. A cliff castle, three miles from Camborne, now encloses only a precipice of over 300 feet.

In vol. ii. of our *Transactions*, pp. 281 and 285, Mr. Philip Rashleigh and Mr. John Hawkins describe the valleys which end at Par. Mr. Hawkins says, "The most important of these appears to be that which deposited the sea-sand, for it indicates *a rise of the sea-level.* And I conceive that the depositions above the sea-sand have gradually usurped the place of the sea and repelled it."

Vol. iii., p. 1, Mr. Hawkins has a paper on "Changes in the County."

C. W. Peach, "Geology of Parts of the Parish of Gorran," read 1842, vol. vi., p. 51.—At Porth Mellin "after heavy gales there are found here *in situ*, near low-water mark, roots of trees with parts of trunks, and also peat."

Richard Q. Couch, "On the Occurrence of Horns and Bones of Deer in Tin-works of Cornwall," vol. vii., p. 185.—"Along the whole of our southern shores from Rame Head, near Plymouth, to Mount's Bay, and, as far as examinations have been made, in different localities from St. Ives to Hartland Point, on

the north, are the remains of a magnificent forest buried beneath the sea, oak, elm, beech, and hazel, horns of the Bovidæ and Cervus, of present and extinct forms, mostly red deer. S. Drew also records horns of a deer seven feet across, from Pentuan." Page 263.—"Deer's horns, ten feet stretch, found Downderry, Portwinkle, to the east of Looe, at Talland, at Polperro, Lanlivet Bay, and Fowey, most numerous at Carnon and Pentuan, found also on Marazion beach and Whitesand Bay, Land's End." Page 265.—"In 1753, twenty feet below the surface in Sennan Bay, pieces of deer and elk's horns were found. Roebuck at Truro Museum."

John W. Colenso, "Pentuan Stream Works," 1829, vol. iv., p. 29.—"The valley falls 120 feet from St. Austell bridge to Pentuan; add the depth of the deposit, it will be a total of 180 feet, or just forty-five feet to the mile.

"(*a*) The tin deposit is from three to six feet and sometimes ten feet thick; it contains roots of oak trees *in situ*, with oyster shells attached to them.

"(*b*) Dark silt, with moss and decomposed vegetable matter twelve inches.

"(*c*) Sludge or silt, ten feet thick, recent shells, wood, hazelnuts, and bones of deer, oxen, etc. The shells, sea ones, are found united. A piece of oak has recently been found worked into shape by man, six feet long, one and a half broad, half thick; small barnacles are attached to one end.

"(*d*) Four inches of sand containing salt; all water above and below is fresh. Above this are several deposits, which have given a human skull and animal remains. Sea must have extended a mile up the valley. The bones of a whale of large size were found in the lower end of the valley."

William Henry Flower, "On the Bones of a Whale found at Pentuan," 1878, vol. ix., p. 114.—"I may, however, mention that the works were some half-mile or more from the present seashore, and about sixty feet in depth, the greater part of which is below the sea-level, and that the whole bones were found at a depth of rather more than twenty feet from the surface in a stratum of sea-sand, above which was a bed of rough river-sand

mixed with gravel, and below were several distinct layers of sea-sand and silt, containing timber trees, chiefly oaks; remains various animals, as red deer, oxen, and boar; human skulls (one of which is now in our Museum); a piece of oak fashioned by human agency; and lower down stumps of trees *in situ*, moss, leaves, hazel-nuts, etc." Once dry land, and afterwards sea, and then filled up.

William Borlase, *Natural History of Cornwall*, 1st edition, 1758, p. 221.—"On the strand of Mount's Bay, midway betwixt the piers of St. Michael's Mount and Penzance, on the 10th of January, 1757, the remains of the wood which, according to tradition, covered anciently a large tract of ground on the edge of Mount's Bay, appeared. The sands had been drawn off from the shore by a violent sea, and had left several places, twenty yards long and ten wide, washed bare, strewn with stones like a broken causeway, and wrought into hollows somewhat below the rest of the sand. This gave me an opportunity of examining the following parts of the ancient trees. In the first pool, part of the trunk appeared, and the whole course of the roots, eighteen feet long and twelve wide, was displayed in a horizontal position; upon spading round, we found the sand to be a thin layer only ten inches deep, and then the natural earth appeared, in which the roots remained so firmly fixed, that, with a pick and crow of iron, we could not get off one piece, but were content to saw off what we could come at. The roots were pierced plentifully by the *teredo*, or auger worm. Three feet in diameter, oak. 300 yards below full-sea mark the water is twelve feet deep upon them when the tide is in."

Rev. John Rogers, "Records Oak from Main Porth Beach," 1832, vol. iv., p. 481.—"The specimen shown came from a stump which apparently was *in situ* about 100 yards below high-water mark. A farmer of the neighbourhood had seen roots thirty yards more to seaward."

Portleven.—Canon Rogers records in a letter to J. A. Paris (published in vol. i. of *Transactions*, p. 236, 1818,) that "a few days ago I observed at the bottom of the basin at Portleven, and embedded in vegetable mould, at the depth of from twenty

to twenty-five feet from the level of the road and a little above watermark, several stumps of oaks and willows, all apparently *in situ*, with their roots extending through the mud. I think they must have been about ten feet below the surface of the sand which formerly occupied the site of the basin, and there must have been either a subsidence of the soil or, what seems more probable, a rise of the sea since the period of their growth; the same theory, whatever it may be, must account for them and for the stumps of oaks mentioned by Borlase, and which are so frequently seen in the Mount's Bay."

Rev. Edward Budge, "Raised Beaches of the Lizard District," vol. vi., p. 1.—"Raised beaches all parallel to existing one, and having caves pierced through them, best seen on the east coast near the Nave, five feet above high water."

Joseph Carne, "Remains of Submarine Forest in the North-eastern Part of Mount's Bay," vol. vi., p. 230.—"Extends half a mile from east to west, from north to south unknown; rarely exceeds four feet eastward from Chyandour river. A number of trunks of trees, most of them entire, lying prostrate in every direction, nearly level with the surface of the sandy beach; the largest is about twenty-six feet, in diameter six to twelve inches." "The deposit extends eastward as far as the pile of rocks called the Eastern Cressars. It generally rests on the clay-slate rock." "Under the Marazion Marsh, near Longbridge, the peat is from four to seven feet thick, resting on sand containing cockle shells (Cardium edule)." "Near Marazion river a pit was sunk to look for tin, and the section of the strata in this pit is interesting. The first eight feet consists of slime gravel and loose ground (the slime having probably been conveyed there by the frequent overflowing of the river); the next four feet consists of a bed of peat, rather soft, full of minute woody fibres, and when dry fit for fuel; below this is a bed of white sand twelve feet in depth, containing a large quantity of Cardium edule; under the sand there is a layer of trees, principally oak and hazel, all prostrate, and lying in all directions, the largest (oak) being about fourteen inches in diameter and thirty feet in length; hazel-nuts are very plentiful, both loose and on the branches." "One piece of oak,

about fourteen feet long, appears to have been wrought, as if it had been intended for the keel of a boat; the trees occupy only from one to two feet in depth." These trees rest on a bed of hard solid peat, three feet thick. Mr. Carne says he believes this bed to be a continuation of that under the sea-level, as the difference of level of these two deposits is very slight. Mr. Carne says some of the old beaches in Land's End district are forty feet above the sea-level.

Miss Carne gives reasons to show these are not raised beaches.

Henry Boase on the submersion of parts of Mount's Bay, 1822, vol. ii., p. 129, in a paper on "Changes in the Cornish Coast."—"The two most remarkable are the submersion of a considerable extent of low woodland, now forming part of Mount's Bay, and the inundation of sand which buried a large tract of cultivated land bordering the sea-coast from St. Ives eastward to beyond Padstow, particularly in the parishes of Lelant, Phillack, Gwithian, Perranzabuloe, Crantock, and St. Enodock." Mr. Boase quotes Florence of Worcester as saying about St. Michael's Mount "that it was formerly five or six miles from the sea, and enclosed with a very thick wood." "Tracing the north-west shore of the bay from the Mount westward to Newlyn, the ebb tide leaves a large space uncovered; the sea-sand is from one to two or three feet deep, and under this stratum of sand is found a black vegetable mould full of woodland detritus, such as the branches, leaves, and nuts of coppice wood, together with the carbonized roots and trunks of forest trees of large growth. All these are manifestly indigenous, and, from the freshness and preservation of some of the remains, the inundation of sand, as well as water, must have been sudden and simultaneous; and the circumstance of ripe nuts and leaves remaining together shows that the irruption happened in the autumn or the beginning of winter. This vegetable substratum has been traced seaward as far as the ebb permits, and is found continuous and of like nature." In regard to the sand hills known as the Green, Mr. Boase records: "The original length of this green (or rather two greens) was about three miles on the east and one mile on the west of Penzance, and is already much shortened. The ancient breadth

is unknown. The oldest notice I have met with is a letter still extant (belonging to the present representative of the Daniell family, Mrs. Ley, of Penzance) which was written in the reign of King Charles II. to the then proprietor of an estate which included part of the western green, and that part is there estimated at *thirty-six acres of pasturage*, of which *part* a small remnant of perhaps two or three acres is all that remains of the *whole green* on this side, which was within the remembrance of persons not long since deceased a mile in length; and it is in the recollection of persons still living that the ground on which the youth of sixty or seventy years ago exercised their contests of cricket and other sports is now swallowed up by the sea. "It is also remarkable that the natural sand, which forms the bed of the sea, is altogether unlike that of the *Green*, being much more comminuted, different in colour, and evidently the pulverized clay slate and elvan of which the rocks of the inner section of the bay are composed." Mr. Boase points out that had Mount's Bay been land from Cudden Point to Mousehole, the cliffs would in long ages have supplied the sands of the mounds —sixteen fathoms. Mr. Boase mentions the well-known fact that in 830 A.D. a great encroachment of the sea is recorded in the *Irish Annals*, and Florence of Worcester says, "On the third day of the nones of November, 1099, the sea came out upon the shore, and buried towns and men very many, oxen and sheep innumerable"; also the Saxon Chronicle, sub anno 1099: "This year, eke on St. Martin's mass day, the 11th Novembere, sprung up so much of the sea-flood, and so myckle harm did, as no man minded that it ever before did, and there was this ylk day a new moon."

Vol. iii., p. 1, Mr. Henry S. Boase has a paper on "Alluvial Formations of the Western Part of Cornwall."—"A point of pilgrimage in the fifth century time of St. Keyna's. Monks were there in King Athelstan's time (ninth century). A change which would make St. Michael's Mount an island would be sure to be recorded. Saxon Chronicle states that on Michaelmas Eve, 1014 A.D., a great sea-flood took place."

Henry S. Boase, "On the Sand-banks of Mount's Bay," vol.

iii., p. 166.—"The dark vegetable mass in which these fragments of wood are embedded consists of decayed plants interspersed with the bark, leaves, and twigs of trees, which are sufficiently perfect to show that they almost entirely belong to the hazel." Hazel-nuts are abundant.

Fragments of insects, elytra of beetles, which still display the most beautiful shining colours when first dug up, said to extend to Newlyn pier.

Copy of letter to Mr. J. B. Cornish:—

"NEWLYN, *Jan. 26th*, 1898.

"MR. CORNISH,—

"Just for information, these specimens of a submarine forest were taken up about 300 or 400 yards from the bridge at Newlyn, which at high water will be sixteen or eighteen feet under. Number 1 is from a tree forty feet long, sixteen inches diameter.

"Number 2 is from a branch twenty-eight feet long, ten inches diameter.

"Number 3 is from a tree sixteen feet long, twelve inches diameter.

"I think they are oak. With respects,

"W. DOWNING, *Boat-builder*,
"Newlyn."

W. A. E. Ussher, "Recent Geology of the Cornish Coast near Padstow," 1879, vol. x., p. 58.—"The first locality, Daymer Bay, Doombar Sands, in the Camel estuary, furnishes an excellent example of submerged forest described seventeen years ago by Mr. Henwood, but now only represented by two or three spongy masses of peaty soil projecting through the sand." In "Pleistocene Notes on the Cornish Coast," he records "that Rev. F. C. Jackson, rector of Ruan, in the Lizard district, informed me at your last meeting that he had observed traces of a submerged forest on the foreshores in that locality. While at Padstow in October I had given me some oak from a tree which was cut through by one of the cylinders of the railway bridge now being erected across the branch of the harbour which comes

down from St. Issey and Little Petherick. The branches of this, or a similar tree, were cut by the cylinder on the Padstow side of the same bridge. This timber was described to me as fifty feet down the cylinder, which was carried before reaching rock to over sixty feet; the soil shown me as that in which the timber was found consisted of dried mud. A bed of shells was cut in the same work at forty-six feet above the timber. The specimen I accepted as a present to our Museum."

S. R. Pattison, "On Post-tertiary Deposits in Cornwall," 1865, vol. vii., p. 36.—"Recently at Maer Lake, near Bude Haven, there has been discovered between high and low water marks a great quantity of soil, to the depth of twenty feet, which is covered by the sea every tide. Many farmers have been drawing it away for manure in preference to sea-sand, and there have been found embedded large trees of enormous size, quite sound, a bullock's horn which measured four feet long and eighteen inches in circumference, and a large stag's horn five feet long and of an enormous size."

From Fenton's *Tour in Pembrokeshire*, 1810.—"A number of trunks of trees are exposed in Porthmawr Bay after heavy storms, consisting of 'various kinds of trees' with the mark of 'ax on them.'" Page 143.—"In February, 1795, a storm coinciding with a spring tide caused an overflowing of Newgall Beach, leaving some pebbles even on the bridge, and forcing the beach several yards inwards. At that time the sand was washed away so as to expose two lines of pebbles parallel, and for a mile in length, these pebbles from one inch to a foot diameter; the soil bare, black, and supporting the firm tread of a horse." At page 471 mention is made of tree stumps of oak, elm, alder, poplar, and sallow.

Frank Rede Fowke, "The Bayeux Tapestry," 1875, p. 141.—"In 709 the town of Dol, in France, was surrounded by a great forest, but by an irruption of the sea was transformed into an island of some mile and a quarter in circumference. The sea retired, leaving the land a swamp, in which lay embedded the *débris* of the ancient forest.

"On the western side of the south island of New Zealand in

a valley on a branch of the Grey river, and near the valley of the Teremakan, is situated a lake called Poerua. This lake has been formed by the outfall being dammed back at some recent time, as by that means only can be explained the curious fact that some Kaiakatea, or white pines, are growing in water of some six feet in depth, while near by a large number of their stumps are still *in situ* under water, presenting a most dangerous feature to boating in that lake." "Rowing carefully through these stumps, which present a little under water a sharp point ready to pierce the bottom of the boat, was a curious experience, much increased by the fact that the boat was old and much worn." "These trees must have grown there before the lake was formed, and as the wood, which is a soft one, decayed away, fallen into the lake, leaving their stumps in fair preservation under water, much as the submarine forest now is.

"Such are a few of the records of the now remaining traces of a forest which must have surrounded the higher parts of Cornwall." "We learn from these remains that the flora consisted of plants now existing, and it has been pointed out that the sea must have covered them at a time that the hazels had nuts and leaves on them, as the hazel-nuts are abundant in most places, some still attached to the branches." "That such an event as the subsidence of a large tract of land in historic times could have taken place I cannot believe. Both the encroachments of the sea mentioned in the *Irish* and *Saxon Annals* are stated to have taken place in November, rather late for hazel-nuts."

Mr. Alex. Somervail's paper on "Absence of Palæolithic Man from Cornwall" records the opinion of geologists that in geological times Cornwall may have extended as far as the 200-fathom line. One thing seems certain: the catastrophe must have been sudden, as if it had been accompanied by a gradual sinking the action of the sea would have washed away all the soil, and with the soil the insect life, leaves, nuts, and all small remains.

Like that of the lost church at Perranzabuloe, the preservation of the smaller remains can be only due to the covering of sand which must have been thrown over them soon after the

subsidence of the land. Several authors mention the marks of the axe as showing human agency. These, if they exist, can be accounted for, I should think, by men finding the wood exposed as it now is after certain gales, and trying with an axe in modern times to see whether it was worth working.

Mr. Collins, on receiving the medal from the President, replied:—

Mr. President, I greatly appreciate the honour which the Council has done me in awarding me this third Bolitho medal, and I am very glad that my name should follow those of Robert Etheridge and Howard Fox, and be further associated with the pleasant memory of William Bolitho. I am glad too to receive it from your hands, which also gave me the Henwood medal some years ago at Truro. Just thirty-one years ago I set foot in this "delectable duchy" and began to study its geology. Although my parents were west-country people, I knew nobody, for they had been for many years resident in London before I was born. But I had some valuable introductions from my dear old friend Robert Hunt, and I soon made the acquaintance of a number of men whose names were already widely known to all students of mining and of mining geology. Such were Robert Were Fox, William Jory Henwood, John and Richard Taylor, William Husband, William West, and John Samuel Enys. It seems strange to stand here full of life and vigour and to remember that these and many more who might be named are all gone; and it is rather humiliating to me to think that, after thirty-one years' study of Cornish geology and Cornish mining, I know so little of these subjects. However, I mean to keep on working at them as long as my time lasts, and I have the satisfaction of knowing that some of my pupils are also working in this field, some indeed who are present in this room to-day. *Ars longa, vita brevis!* If one man's thirty years will not do much, the similar labours of many men will surely give us in the end all the light we require on the origin and geological history of this most interesting region. I think, sir, that these medals

should serve as strong incentives to our young students, and in particular I would urge on this occasion our need of fossil-collectors in all parts of Cornwall. There are still areas of scores or even hundreds of square miles of stratified rocks in which no fossils have as yet been found, and where, consequently, we cannot say with certainty what is the age of the rocks. Some of these are perhaps absolutely unfossiliferous, but that used to be said of the whole county before it yielded the rich collections in our cases below to the labours of John Phillips, S. R. Pattison, Charles Peach, and their successors and associates.

REPORT OF THE COUNCIL.

THE *Transactions* of this Society for the last year were not sent out until a date which was considerably later than is usual. This was due to the completion of the plates accompanying the paper which embodies the results of Mr. A. Bell's research into the now famous pliocene shell-beds at St. Erth. Mr. Bell unfortunately sustained a severe bereavement during the time when the proofs were being revised, and the Council take this opportunity of expressing their sympathy with him. This and the revisions necessary to ensure complete accuracy in the drawings prevented the officers of the Society from placing the printed number in the hands of the members at the usual time. The Council believe that the importance of the matter justifies the care which was taken, and desire to be allowed to record the thanks of the Society to Mr. Bell, and to all those who assisted him, and especially Mr. Enys, who was the original promoter of the undertaking. The sheils themselves which Mr. Bell collected, two of which are entirely new to scientific knowledge, and specimens of the clays from the beds, are now in the Museum.

The members will be glad to learn that Mr. J. B. Hill having now recovered, we hope completely, from the illness which incapacitated him from work so soon after his arrival in the county, has made a good beginning of the new geological survey which the Council last year had the pleasure of announcing had been ordered by the Geological Survey Office. They hope Mr. Hill will be able to give an account of the progress of his work at this meeting. They are also pleased to announce that another surveyor, Mr. G. B. Wilkinson, has been stationed at Penzance, who has already commenced work in the Land's End district. The Council feel assured that the members will be pleased to know that the efforts which this

Society made to get the survey undertaken have met with such cordial response.

Mr. J. H. Collins has during the year kindly continued his valuable rearrangement of the Museum. The Council have decided to recommend that the William Bolitho medal for the year be presented to Mr. Collins, feeling that he has thoroughly earned that distinction both by his distinguished position in the world as a geologist and by the invaluable assistance which he has so often rendered to this Society.

A mining exhibition is to be held in connection with the Greater Britain Exhibition at Earl's Court next year. The Hon. Secretary of this Society has already been in correspondence with the London Chamber of Mines, the body which has the control of this particular part. The question of representing Cornwall at the Exhibition was mentioned at the joint meeting of the Cornish scientific societies at Truro in September last. The Council think that Cornwall should if possible be represented at any exhibition relating to mining, and they will be prepared to do anything which they can to further that result. The very short notice which has been given of the Exhibition and the high prices which are quoted for space for exhibits are the great difficulties which now stand in the way.

During the year a large number of people have visited the Museum, no less than 233 names being recorded in the visitors' book. The report of the Librarian shows how greatly the Library has been increased. The necessity for erecting new shelves has been postponed by a rearrangement of the volumes.

We have lost by death Major-General C. W. Tremenheere, one of our honorary members, and also one of our oldest members, who was known and admired throughout Cornwall—Miss L. M. Fox, of Pengerrick.

The Council recommend the election of Dr. G. J. Hinde, F.R.S., Lieut.-Col. McMahon, V.P.G.S., and the Rev. W. Colenso, of Napier, New Zealand, as honorary members, and record the election of four new members during the year.

The Council recommend the re-election of Mr. J. D. Enys as President for the next two years.

LIBRARIAN'S REPORT

From November 1st, 1897, to October 31st, 1898.

THE following works have been added to the Library during the year:—

I. TRANSACTIONS, JOURNALS, AND REPORTS.

Presented by the respective Societies, Editors, and other Donors, or Purchased.

Adelaide. South Australian School of Mines and Industries and Technological Museum.

Ninth Annual Report, 1897. 8vo. Adelaide, 1898.

Boston. American Academy of Arts and Sciences.

Proceedings: Vol. xxxii., Nos. 16 and 17, June and July, 1897. Including Title-page and Contents of vol. xxxii.

Proceedings: Vol. xxxiii., Nos. 1–27, July, 1897, to July, 1898. Including Title-page, Index, and Contents of vol. xxxiii.

Proceedings: Vol. xxxiv., No. 1, August, 1898. Roy. 8vo. Boston, 1897–1898.

Bristol. Naturalists' Society.

Proceedings: Vol. viii, part 2, New Series, 1896–1897. 8vo. Bristol, 1898.

Brussels. Société Royale Malacologique de Belgique.

Procès Verbal:

Vol. xxiv., pp. 85–122, June to December, 1895.
Vol. xxv., pp. 1–80, January to December, 1896.
Vol. xxvi., pp. 1–56, January to December, 1897.
Vol. xxvii., pp. 1–72, January to July, 1898.
8vo. Brussels, 1895–1898.

Buenos Aires. Museo Nacional.

Anales: Tomo v. (Ser. 2a, t. ii.).
Imp. 8vo. Buenos Aires, 1896–1897.

Memorias 1894, 1895, and 1896, de dicho Museo.
Imp. 8vo. Buenos Aires, 1897.

Comunicaciones: Tomo i., No. 1.
8vo. Buenos Aires, 1898.

Buffalo. Society of Natural Sciences.

Bulletin: Vol. v., Nos. 1–5, July, 1896, to July, 1897. Including Title-page and Contents of vol. v.

Bulletin: Vol. vi., No. 1, February, 1898.
8vo. Buffalo, N.Y., 1886–1898.

Cambridge. Library Syndicate.

Forty-fourth Annual Report for the year ending December 31st, 1897. 4to. Cambridge, 1898.

Canada. Canadian Institute.

Transactions: Vol. v., part 2, No. 10, May, 1898. Including Title-page and Contents.

Transactions Supplement to vol. v., part 1, No. 9. Plates to accompany Dr. Maclean's paper on picture writing of the Black Feet. Roy. 8vo. Toronto, 1898.

Proceedings: Vol. i., parts 4–5, Nos. 4–5, May, 1898.
Roy. 8vo. Toronto, 1898.

——. Geological Survey of Canada.

Palæozoic Fossils: Vol. iii., part 3. By J. F. Whiteaves, F.G.S., F.R.S.C., etc. Roy. 8vo. Ottawa, 1897.

——. Natural History Society of Montreal.

The Canadian Record of Science: Vol. vii., parts 5–7.
8vo. Montreal, 1898.

——. Royal Society of Canada.

Proceedings and Transactions: Second Series, vol. ii., May, 1896. Imp. 8vo. Ottawa, 1896.

Cincinnati. Society of Natural History.

Journal: Vol. xix., Nos. 3–4, November, 1897, to July, 1898. 8vo. Cincinnati, 1897–1898.

Colorado. Scientific Society.

Proceedings (in separate pamphlets), viz.:—

Some Products found in the Hearth of an Old Furnace upon the Dismantling of the Trethellan Tin Works, Truro, Cornwall. By W. P. Headden, Ph.D. Read November 6th, 1897.

An Olivinite Dyke of the Magnolice District and the Associated Pierotitanite. By Milton C. Whitaker. Read February 5th, 1898. 8vo. Denver, 1897–1898.

A Mineralogical Mistake. By P. H. Van Diest. Read May 7th, 1898. 8vo. Denver, 1898.

Vol. v., 1894–1896. Including Title-page and Index. 8vo. Denver, 1897.

Dorpat. Dorpater Naturforscher-Gesellschaft.

Sitzungsberichte: Band xi., heft 3, 1898. 8vo. Dorpat, 1898.

Dublin. Royal Dublin Society.

Scientific Transactions: Vol. v., series ii., part 13, July, 1896. Including Title-page and Contents of vol. v.

Scientific Transactions: Vol. vi., series ii., parts 2–13, May, 1896, to November, 1897. 4to. Dublin, 1896–1897.

Scientific Proceedings: Vol. viii., New Series, part 5, July, 1897. 8vo. Dublin, 1897.

Edinburgh. Geological Society.

Transactions: Vol. vii., part 3. Laws and List of the Society. 8vo. Edinburgh, 1897.

——. Royal Society of Edinburgh.

Proceedings: Vol. xxi., Sessions 1895–1897. 8vo. Edinburgh, 1897.

Falmouth. Royal Cornwall Polytechnic Society.
Sixty-fifth Annual Report, 1897. 8vo. Falmouth, 1897.
[Including General Index of Annual Reports from No. 45 (1879) to No. 65 (1897), both inclusive.]

Freiberg. Jahrbuch für das Berg-und Hüttenwesen im Königreiche Sachsen auf das Jahr, 1897.
Imp. 8vo. Freiberg, 1897.

Havre. Société Géologique de Normandie.
Bulletin: Tome xvii. Années. 1894–1895.
Roy. 8vo. Havre, 1896.

India. Geological Survey of India.
General Report on the Work carried on for the Period from 1st January, 1897, to the 1st April, 1898.
Roy. 8vo. Calcutta, 1898.

Memoirs: Vol. xxvii., part 2. Roy. 8vo. Calcutta, 1897.
[Including Title-page and Index of vol. xxvii.]

Palæontologia Indica: Series xv., vol. 1, part 4.
" " " vol. 2, part 1.
" " Series xvi., vol. 1, parts 2–3.
With Plates. 4to. Calcutta, 1897.

Records: Vol. xxx., part 4, 1897.
Roy. 8vo. Calcutta, 1897.
[Including Title-page and Contents of vol. xxx.]

Indiana. Academy of Science.
Proceedings, 1896. Roy. 8vo. Indianapolis, 1897.

Department Geology and Natural Resources.
Twenty-second Annual Report, 1897. By W. S. Blatchley, State Geologist. Roy. 8vo, cloth. Indianapolis, 1898.
[Presented by W. S. Blatchley.]

Iowa. Geological Survey.
Report on Lead and Zinc, Artesian Wells, etc., vol. vi.
4to. Des Moines, Iowa, 1897.

Annual Report, vol. vii., 1896.
4to. Des Moines, Iowa, 1897.

Kansas. Academy of Science.

Transactions of the Twenty-eighth and Twenty-ninth Annual Meetings, 1895–1896, vol. xv.

Roy. 8vo, cloth. Topeka, Kansas, 1898.

——. University.

Quarterly: Vol. vii., No. 2, April, 1898.

Roy. 8vo. Lawrence, Kansas, 1898.

Leicester. Literary and Philosophical Society.

Transactions: Vol. iv., part 10, October, 1897.

" " " 11, January, 1898.

" " " 12, April, 1898.

8vo. Leicester, 1897–1898.

[Including Rules, Title-page, and Index to vol. iv.]

Liverpool. Engineering Society.

Transactions: Vol. xix., Session xxiv.

8vo. Liverpool, 1898.

[Including Library Catalogue and Index to Transactions 1875–1898.]

——. Geological Association.

Journal: Vol. xvi,. Session 1895–1896.

8vo. Liverpool, 1896.

——. Geological Society.

Proceedings: Vol. viii., part 1, Session xxxviii.

" " " 2 " xxxix.

8vo. Liverpool, 1897–1898.

London. British Association for the Advancement of Science.

Report of the Sixty-seventh Meeting, held at Toronto in August, 1897. 8vo, cloth. London, 1898.

——. Geologists' Association.

Proceedings: Vol. xv., parts 5-9, November, 1897, to August, 1898. 8vo. London, 1897–1898.

List of Members and Exchanges, February, 1898.

8vo. London, 1898.

London. Geological Society of London.

Quarterly Journal:

Vol. liii., part 4, No. 212, December, 1897. Including Index and Title-page and Contents of vol. liii.

Vol. liv., part 1, No. 213, February, 1898.
" " 2 " 214, May, 1898.
" " 3 " 215, August, 1898.
8vo. London, 1897–1898.

Catalogue of Geological Literature added to the Society's Library during the year ended December 31st, 1897.
8vo. London, 1898.

List, November 2nd, 1897. 8vo. London, 1897.

——. London, Edinburgh, and Dublin Philosophical Magazine.

Series v., vol. xliv., Nos. 270, 271, November and December, 1897. Including Index, Title-page, and Contents of vol. xliv.

Series v., vol. xlv., Nos. 272–277, January to June, 1898. Including Index, Title-page, and Contents of vol. xlv.

Series v., vol. xlvi., Nos. 278–281, July to October, 1898.
8vo. London, 1897–1898. *Purchased.*

——. Mines and Quarries.

General Report and Statistics for 1897. Two Parts.

Part 1. Statistics of the Persons employed: Output and Accidents at Mines and Quarries in the United Kingdom, arranged according to the Inspection Districts.

Part 2. General Reports and Statistics relating to Persons employed and Accidents at Mines and Quarries in the United Kingdom, and to the Enforcement of the Mines and Quarries Acts. Edited by C. Le Neve Foster, D.Sc., F.R.S.
Folio. London, 1898.
[Presented by C. Le Neve Foster, Esq.]

London. Mines.

List of the Plans of Abandoned Mines deposited in the Home Office, including Plans transferred from the late *Mining Record Office*, corrected to the 31st December, 1897. 4to. London, 1898.

[Presented by C. Le Neve Foster, Esq.]

——. Palæontographical Society.

Vol. li., for 1897. 4to. London, 1897. *Purchased.*

——. Royal Society.

Proceedings:

Vol. lxii., Nos. 381–388, December, 1897, to April, 1898. Including Index, Title-page, and Contents of vol. lxii.

Vol. lxiii., Nos. 389–401, April to July, 1898. Including Index, Title-page, and Contents of vol. lxiii.

Vol. lxiv., Nos. 402–403, August to September, 1898.

Year Book, Nos. 1 and 2. 1897–1898.
8vo. London, 1897–1898.

Manchester. Art Museum.

Annual Report, 1897–1898. 8vo. Manchester, 1898.

——. Geological Society.

Transactions: Vol. xxv., parts 12–21, Session 1897–1898.
8vo. Manchester, 1898.

——. Geographical Society.

Journal: Vol. xi., Nos. 10–12, October to December, 1895.
„ „ xii. „ 9–12, October to December, 1896.
„ „ xiii. „ 1–12, January to December, 1897.
„ „ xiv. „ 1–6, January to April, 1898.
8vo. Manchester, 1895–1898.

——. Museum, Owen's College.

Report of the Keeper of the Museum for the year 1897–1898.
8vo. Manchester, 1898.

Meriden. Scientific Association.
Transactions: Vol viii., 1897–1898. 8vo. Meriden, 1898.

Mexico. Instituto Geológico de México.
Boletin: Num. x. 4to. Mexico, 1898.

Montevideo. Museo Nacional de Montevideo.
Anales: Tomo ii., Fasgigulo viii.
„ „ iii, Fasgigulo ix. 4to. Montevideo, 1898.

Netherlands India. Jaarboek van het Mijnwezen in Nederlandsch Oost-Indië Uitgegeven op last van Zijne Excellentie den Minister Van Koloniën. 27th year, 1898. Technisch-Administratief en Wetenschappelijk Gedeelite. 8vo. Amsterdam, 1898.

Newcastle-upon-Tyne. North of England Institute of Mining and Mechanical Engineers.
Transactions: Vol. xlvi., part 4, issued May, 1897.
„ „ „ 5 „ August, 1897.
„ „ „ 6 „ February, 1898.
„ Vol. xlvii. „ 1 „ December, 1897.
„ „ „ 2 „ January, 1898.
[Including Title-page and Contents of vol. xlvi.]

Transactions: Vol. xlvii., part 3, issued April, 1898.
„ „ „ 4 „ May, 1898.
„ „ „ 5 „ July, 1898.
Royal 8vo. Newcastle-upon-Tyne, 1897–1898.

Annual Report of the Council for the year 1896–1897 and List of Officers, etc., for the year 1897–1898.
Royal 8vo. Newcastle-upon-Tyne, 1897.

An Account of the Strata of Northumberland and Durham as proved by Borings and Sinkings.
Royal 8vo. Newcastle-upon-Tyne, 1897.

New South Wales. Australasian Association for the Advancement of Science.

Experiments on Waterproofing of Bricks and Sandstones with Oils, and upon the Porosity of Plasters and Cements; Variation in the Amount of Free and Aluminoid Ammonia in Waters on Keeping; On the Corrosion of Aluminium; Crystallised Carbon Dioxide; On the Internal Structure of Gold Nuggets; Contributions to the Bibliography of Gold; On the Crystalline Structure of Gold and Platinum Nuggets and Gold Nuggets. By A. H. Liversidge, LL.D., F.R.S. 8vo. Sydney, N.S.W., 1895.

Sydney Session, 1898.

Address by Professor Liversidge, M.A., LL.D., F.R.S., President. 8vo. Sydney, N.S.W., 1898.

——. Department of Mines and Agriculture.

Annual Report for the year 1897.
4to. Sydney, N.S.W., 1898.

Records of the Geological Survey. Vol. v., parts 3-4.
4to. Sydney, N.S.W., 1897-1898.

Mineral Resources.

No. 1. Notes on Chromic Iron Ore: its Modes of Occurrence, Mining, Dressing, Uses, and Value.

No. 2. Notes on the Occurrence of Tungsten Ores in New South Wales, with Registers of Localities in New South Wales. By J. E. Carne, F.G.S.
8vo. Sydney, N.S.W., 1898.

No. 3. Notes on Gold Dredging, with reference to the Introduction of the Industry into New South Wales. By J. B. Jaquet, A.R.S.M., F.G.S., Geological Surveyor.
8vo. Sydney, N.S.W., 1898.

——. Royal Society of New South Wales.

Journal and Proceedings: Vol. xxxi., 1897. Including Index and Title-page. 8vo. Sydney, N.S.W., 1898.

New York. Academy of Sciences (late Lyceum of Natural History).

Annals:

Vol. ix., Nos. 6–12, August, 1897. Including Index and Title-page of vol. ix., 1896–1897.

Vol. xi., part 1, April, 1898.

8vo. New York, 1897–1898.

Transactions: Vol. xvi., October, 1896, to December, 1897. Including Index and Title-page.

Royal 8vo. New York, 1898.

——. American Geographical Society.

Bulletin:

Vol. xxix., Nos. 3 and 4, 1897. Including Index, Title-page, and Contents of vol. xxix.

Vol. xxx., Nos. 1–3, 1898.

8vo. New York, 1897-1898.

——. American Museum of Natural History.

Bulletin:

Vol. ix., 1897. Including Index, Title-page, and Contents of vol. ix.

Vol. xi., part 1, 1898.

Royal 8vo. New York, 1897–1898.

Annual Report of the President for the year 1897.

8vo. New York, 1898.

——. Teachers' College.

Journal of School Geography: Vol. i., No. 10, December, 1897. 8vo. New York, 1897.

North Carolina. Elisha Mitchell Scientific Society.

Journal: Vol. xiv., parts 1–2, January to December, 1897.

8vo. Chapel Hill, N.C., 1897.

Nova Scotia. Nova Scotian Institute of Science.

Proceedings and Transactions (Second Series): Vol. ix., part 3, Session of 1896–1897.

8vo. Halifax, N.S., 1897.

Philadelphia. Academy of Natural Sciences.

Proceedings:

Parts 2–3, April to December, 1897. Including Index and Title-page.

Part 1, January to March, 1898.

Royal 8vo. Philadelphia, 1897–1898.

——. American Philosophical Society.

Proceedings:

Vol. xxxv., No. 153, December, 1896.

„ xxxvi. „ 154, January, 1897.

„ „ Nos. 155–156, May to December, 1897. Including Index to vol. xxxvi.

„ xxxvii., No. 157, July, 1898.

8vo. Philadelphia, 1896–1898.

Transactions: Vol. xix. (New Series), part 2.

4to. Philadelphia, 1898.

——. Wagner Free Institute of Science.

Transactions: Vol. v., January, 1898.

Imp. 8vo. Philadelphia, 1898.

Pisa. Società Toscana di Scienze Naturali.

Processi Verbali: Vol. x., pp. 202–292.

„ „ „ xi., pp. 1–56.

Royal 8vo. Pisa, 1898.

Plymouth. Plymouth Institution and Devon and Cornwall Natural History Society.

Annual Report and Transactions, 1897–1898: Vol. xii., part 4. 8vo. Plymouth, 1898.

Rio de Janeiro. Museu Nacional.

Revista do Museu Nacional do Rio de Janeiro: Vol. i. (Seguimento aos Archivos do Museu Nacional: Vol. ix.)

4to. Rio de Janeiro, 1896.

Sweden. Geological Institution (University of Upsala).

Bulletin: Vol. iii., part 2, No. 6, 1896–1897.

Royal 8vo. Upsala, 1898.

Truro. Royal Institution of Cornwall.

Journal: Vol. xiii., part 2, 1896.

„ „ „ 3, 1897. 8vo. Truro, 1897–1898.

United States. Department of the Interior. Geological Survey.

Seventeenth Annual Report, 1895–1896. By Charles D. Walcott, Director. Two Parts. Part 1 containing Report of the Directors and other Papers: "Magnetic Declination in the United States," by Henry Gannett; "A Geological Reconnaissance in North-western Oregon," by J. S. Diller; "Further Contributions to the Geology of the Sierra Nevada," by H. W. Turner; "Report on Coal and Lignite of Alaska," by W. H. Dall; "The Uintaite (Gilsonite) Deposits of Utah," by G. H. Eldridge; "Glacial Brick Clays of Rhode Island and South-eastern Massachusetts," by N. S. Shaler, J. B. Woodworth, and C. F. Marbut; "The Faunal Relations of the Eocene and Upper Cretaceous of the Pacific Coast," by T. W. Stanton. Part 2.—Economic Geology and Hydrography: "The Gold-quartz Veins of Nevada City and Grass Valley, California," by Waldemar Lindgreen; "Geology of Silver Cliff and the Rosita Hills, Colorado," by Whitman Cross; "The Mines of Custer County, Colorado," by S. F. Emmons; "Geological Section along the New and Kanawha Rivers, in West Virginia," by M. R. Campbell and W. C. Mendenhall; "The Tennessee Phosphates," by C. W. Hayes; "The Underground Water of the Arkansas Valley, in Eastern Colorado," by G. H. Gilbert; "Preliminary Report on Artesian Waters of a Portion of the Dakotas," by N. H. Darton; "The Water Resources of Illinois," by Frank Leverett.

4to, cloth. Washington, 1896.

——. Monographs:

Vol. xxv. The Glacial Lake Agassiz. By Warren Upham. 1895.

Vol. xxvi. The Flora of the Amboy Clays. By John Strong Newberry. 1895.

United States. Monographs:

Vol. xxvii. Geology of the Denver Basin in Colorado. By Samuel Franklin Emmons, Whitman Cross, and George Homans Eldridge. 1896.

Vol. xxviii. The Marquette Iron-bearing District of Michigan, with Atlas. By Charles Richard Van Hise and William Shirley Bayley. Including a chapter on the Republic Trough. By Henry Lloyd Smith. 1897.

4to, cloth. Washington, 1895–1897.

——. Bulletins:

No. 87. A Synopsis of American Fossil Brachiopoda, including Bibliography and Synonymy.—Schuchert.

No. 127. Catalogue and Index of Contributions to North American Geology, 1732–1891.—Darton.

No. 130. Bibliography and Index of North American Geology, Palæontology, Petrology, and Mineralogy for 1892–1893.—Weeks.

No. 135. Bibliography and Index of North American Geology, Palæontology, Petrology, and Mineralogy for 1894.—Weeks.

No. 136. The Ancient Volcanic Rocks of South Mountain, Pennsylvania.—Bascom.

No. 137. The Geology of the Fort Riley Military Reservation and Vicinity, Kansas.—Hay.

No. 138. Artesian Well Prospects in the Atlantic Coastal Plain Region.—Darton.

No. 139. Geology of the Castle Mountain Mining District, Montana.—Weed and Pirsson.

No. 140. Report of the Progress of the Division of Hydrography for the calendar year 1895.—Newell.

No. 141. The Eocene Deposits of the Middle Atlantic Slope in Delaware, Maryland, and Virginia.—Clark.

No. 142. A Brief Contribution to the Geology and Palæontology of North-western Louisiana.—Vaughan.

No. 143. Bibliography of Clays and the Ceramic Arts.—Branner.

No. 144. The Moraines of the Missouri Coteau and their Attendant Deposits.—Todd.

United States. Bulletins:

No. 145. The Potomac Formation in Virginia.—Fontaine.

No. 146. Bibliography and Index of North American Geology, Palæontology, and Mineralogy, for 1895.—Weeks.

No. 147. Earthquakes in California, 1895.—Perrine.

No. 148. Analysis of Rocks and Analytical Methods, W.S. Geological Survey, 1880–1896.—Clarke and Hillebrand.

8vo. Washington, 1897.

——. Geologic Atlas of the United States.

Folios 26–37. Elephant folio. Washington, 1896–1897.

Victoria. Australasian Institute of Mining Engineers.

Proceedings: Report of the Annual Meeting.

Report of the First Ordinary Meeting, held at Launceston, Tasmania, April 12th, 1898. 8vo. Melbourne, 1898.

Transactions: Vol. v. 8vo. Melbourne, 1898.

——. Department of Mines.

Annual Report of the Secretary for Mines and Water Supply. Including Reports on the Working of Part iii. of Mines Acts, 1890 and 1897; Water Supply, etc., etc., during the year 1897. Folio. Melbourne, 1898.

——. Geological Survey of Victoria.

Progress Report (No. 9). Reports on Leads.

4to. Melbourne, 1898.

Vienna. K.K. Geologischen Reichsanstalt.

Verhandlungen: Nos. 11–18, 1897. Including Index and Title-page for vol.

Verhandlungen: Nos. 1–12, 1898.

Royal 8vo. Wien, 1897–1898.

Washington. Smithsonian Institution.

Annual Report of the U.S. National Museum for the year ending June 30th, 1895.

Royal 8vo, cloth. Washington, 1897.

Yorkshire. Geological and Polytechnic Society.

Proceedings: Vol. xiii., part 3, pp. 279-374 (New Series).

8vo. Yorkshire, 1898.

II. GEOLOGICAL AND MISCELLANEOUS PUBLICATIONS.

Presented by the Authors or other Donors.

Collins, J. H. Newfoundland: its Mineral and other Resources. A lecture by J. H. Collins, F.G.S., delivered at the Imperial Institute, March 7th, 1898. 8vo. London, 1898.

Cornish Mines and Cornish Miners. By J. H. Collins, F.G.S. 8vo. London, 1897.

On the Origin and Development of Ore Deposits in the West of England. By J. H. Collins, F.G.S. 8vo. London, 1898.

[Presented by the Author.]

Eathorne, J. R. Piscatory; or, Fish and Fishermen. By John Richards Eathorne. Demy 8vo. Sydney, N.S.W., 1897.

[Presented by the Author.]

Holland, T. H. On a Quartz-Barytes Rock occurring in the Salem District, Madras Presidency. By T. H. Holland, A.R.C.S., F.G.S. Royal 8vo. Calcutta, 1897.

[Presented by the Author.]

Prestwich, Sir Joseph. The Solent River: Drift Deposits in Britain. By the late Sir Joseph Prestwich, M.A., D.C.L., F.R.S. 8vo. London, 1897.

[Presented by Lady Prestwich.]

Smyth, H. W. Five Years in Siam: from 1891 to 1896. Two Volumes. By H. Warington Smyth, M.A., LL.B., F.G.S., F.R.G.S. Royal 8vo, cloth. London, 1898.

[Presented by the Author.]

CURATOR'S REPORT.

Shells, St. Erth beds.	A. Bell, F.G.S.
Clays „ „	
Wood from the submerged forest, Mount's Bay	J. Downing.
Gold, Orgum Mine, Mysore, India.	W. Eddy.
Silver ore, Emma Mine, Salt Lake City, U.S.A.	
Fossils from chalk, Greenhithe, Gravesend.	R. Permewan.

TREASURER'S STATEMENT, 1897-98.

Dr. *The Treasurer in Account with the Royal Geological Society of Cornwall.* **Cr.**

November 8th, 1898—	£	s.	d.
To Ordinary Subscriptions and Arrears	50	8	0
,, Donation per H.R.H. The Prince of Wales ...	20	0	0
,, One Year's Dividend on £1500 Midland Railway 3% Debenture Stock, less tax, 30/-	43	10	0
,, Donation per J. D. Enys, Esq.	16	0	0
,, Sale of Transactions	1	14	0
,, Balance	37	14	7
	£169	6	7

November 9th, 1897—	£	s.	d.
By Balance	16	14	11
November 8th, 1898—			
By Rates and Taxes	0	12	0
,, Housekeeper's Salary	20	0	0
,, Curator's Salary	50	0	0
,, Insurance Premium	2	12	9
,, Books, Binding, &c.	51	9	7
,, Coals, Gas, &c.	9	19	10
,, Repairs to Buildings	0	13	2
,, Painting ,, ...	6	17	6
,, Palæontographical Society	2	2	0
,, Sundry Expenses per Secretary — Stationery, Postages, Cleaning, &c.	8	4	10
	£169	6	7
,, Balance due to Treasurer	37	14	7

T. ROBINS BOLITHO, *Treasurer.*

PENZANCE.

Dr. *The Treasurer in Account with the Royal Geological Society of Cornwall.* **Cr.**

DEPOSIT—OLD ACCOUNT.

			£	s.	d.
1896—November 10th.	To Balance ...	..	41	13	7
1897— ,, 9th.	,, Interest to Date	...	1	18	0
		£43	11	7	
1898— ,, 8th.	,, ,,	...	1	1	6
		£44	13	1	

LATE W. BOLITHO, JUN., LEGACY ACCOUNT.

			£	s.	d.
1897—November 9th.	To Balance	...	511	16	0
1898— ,, 8th.	,, One Year's Interest to April 5th ...	...	12	15	6
		£524	11	6	

			£	s.	d.
1899—March 1st.	Gerrard and Co. for 1898 Gold Medal	...	13	4	0
Balance		...	511	7	6
		£524	11	6	

PENZANCE.

T. ROBINS BOLITHO, *Treasurer.*

LIST OF

PAPERS READ AT THE ANNUAL MEETING,

November 8th, 1898.

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1. Some New Fossils from the South Coast of Cornwall. By Upfield Green, F.G.S.

2. Pteraspis Cornubica from Lantivet Bay. By A. Smith Woodward, F.G.S.

3. The Lower Palæozoic Rocks of Scotland and those of Cornwall. By J. Bastian Hill.

4. Recent Discoveries of Gold in West Cornwall. By Francis J. Stephens, F.G.S.

5. Notes on Cornish Fossils. By J. H. Collins, F.G.S.

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Plate F.

1.

4.

5.

Section of 1.

2.

3.

NEREITOPSIS CORNUBICUS.

ON SOME NEW AND PECULIAR FOSSILS FROM THE LOWER DEVONIANS OF THE SOUTH COAST OF CORNWALL.

By Upfield Green, F.G.S.

Communicated by J. H. Collins, F.G.S.

(Read November 8th, 1898.)

While engaged collecting specimens of the fossil Devonian fauna of Cornwall for comparison with that of the Continent, two attracted my attention from their dissimilarity to any yet recorded as occurring in the county, and which are, I believe, undescribed in Devonian literature.

I have, therefore, prepared illustrations of the same (Figs. 1 and 2 on the accompanying plate, F), as also of a specimen (Fig. 3) discovered by Mr. Collins in the Society's collection at Penzance. Fig. 4, from the same source, presents also some general points of resemblance.

I have named the fossil *Nereitopsis cornubicus*, from its somewhat distant resemblance to some of the species of the genus *Nereis* (Cuvier) of the dorsibranchiate order of Annelids; I believe that the discovery of more perfect specimens will confirm my view.

Unfortunately, none of the specimens yet found are in a condition enabling any description of the appendages of the head to be given.

The larger specimen (Fig. 1) differs from the others, being terminated posteriorly by a tuberculated extension.

Fig. 1 represents the specimen found at Pont Quarry, Polruan, and Fig. 5 is a cross-section of the same specimen; Fig. 2 is from Polyne Quarry, two miles north from Looe; Figs. 3 and 4 are from the specimens found by Mr. Collins in the Society's collection in the Lower Museum.

I shall have pleasure in presenting the two specimens found by me to the Museum of the Royal Geological Society of Cornwall as soon as I have done with them.

ON SOME NEW SPECIMENS OF *PTERASPIS CORNUBICA* FROM THE DEVONIAN OF LANTIVET BAY.

By A. Smith Woodward, F.L.S.

(Read November 8th, 1898.)

It has long been recognised that the finely ribbed fish-plates occurring in the Devonian rocks of Southern Cornwall are Pteraspidian in their nature. They have sometimes received the name of *Scaphaspis*,[1] which now proves to be applicable to the ventral shield of any member of the family; more recently they have been provisionally ascribed to the genus *Pteraspis*.[2] All the known specimens, however, are very fragmentary; and hitherto there have been no means of determining their generic relationships. A specimen recently submitted to me by Mr. J. H. Collins and two other specimens in the British Museum now seem to furnish the necessary facts for this determination, and indicate that, so far as the dorsal armour is concerned, the Cornish species truly belongs to the type-genus *Pteraspis*.

[1] H. Woodward and E. Ray Lankester, *Geol. Mag.*, vol. v. (1868), p. 248.

[2] J. H. Collins, *Trans. R.G.S. Corn.*, vol. xi. (1893), p. 59.

The specimen discovered by Mr. C. W. Peach in Lantivet Bay, and submitted to me by Mr. Collins, exhibits the hinder portion of the median disc of the dorsal armour, with the base of the median spine rising as usual from a short longitudinal fissure in the posterior margin of this plate. The fossil is vertically crushed and much distorted, and does not appear to exhibit any of the true border of the disc; but the characteristic ribbed ornament is distinct, and this is disposed exactly as in the typical species of *Pteraspis*. The terminal portion of the spine is also broken away, but it is shown to have been much laterally compressed, while its basal part is clearly marked by the fine longitudinal ribbing.

The first important specimen in the British Museum, already mentioned (No. P. 7156), is a smaller fragment of the median disc with the base of the posterior spine. This also exhibits the characteristic ribbed ornament; and in transverse section both the disc and the spine show the large internal cancellæ. As preserved, the spine is somewhat more elevated than in the previous specimen; but the difference is probably due to the lateral direction of the distortion during fossilisation in this case.

The second specimen in the British Museum worthy of special note is a detached left orbital plate (No. P. 7155), shaped precisely as in the typical *Pteraspis rostrata*. Its inwardly directed portion seems to be partly broken away, but the

other borders are evidently complete, and the postero-external process is well preserved. The orbit is distinct, oval in shape, with its long axis directed antero-posteriorly. A small portion of the inner cancellated layer of the plate is exposed below the orbit; but the remainder of the external surface is well preserved, with the characteristic ribbed ornamentation, which is concentric round the orbit, but more or less longitudinal and converging along the outer margin and posterior process.

It is thus evident that the Cornish Devonian Pteraspidian has a complete dorsal shield, that the orbit is completely surrounded by a special orbital plate, and that a short dorsal spine is fixed in a cleft at the hinder border of the median disc. These in combination are the special characters of *Pteraspis* as now defined, and prove, as already mentioned, that the Cornish species is correctly described under the name of *P. cornubica*. It seems to be the largest species of the genus hitherto discovered; for the maximum antero-posterior measurement of the orbital plate is about 0·04 m., whereas that of the largest known *P. rostrata* does not exceed 0·025 m., while the fragments of disc also denote at least the same unusual proportions. The dorsal shield of the *P. rostrata* in question attains a length of about 0·14 m. The corresponding shield of *P. cornubica* thus probably measured approximately 0·25 m. in length.

It may be added that in Western Europe *Pteraspis* is characteristic only of the Lower Devonian or Lower Old Red Sandstone, not descending below the base of this formation, where it is preceded by a simple shield, *Cyathaspis*. In Galicia, however, typical species occur in strata which are claimed to be of Downtonian or even Ludlow age.[1]

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[1] See synopsis of species in A. S. Woodward's *Catalogue of Fossil Fishes in the British Museum*, vol. ii. (1891), pp. 160–169.

NOTES ON CORNISH FOSSILS IN THE PENZANCE MUSEUM.

By J. H. Collins, F.G.S.

(Read November 8th, 1898.)

V. NOTES OF PROGRESS.

(*a*) The Working Catalogue. This has now reached No. 1531. There are still many specimens to be fixed on tablets, numbered and named, and new ones are constantly coming in from various sources and donors.

(*b*) Table Cases in Lower Museum. These were originally provided and set aside by the Council for the display of the important collection of Cornish palæozoic fossils for which the Society is indebted to the labours of Mr. Peach and many other collectors. My little leisure while in Cornwall for some years past has been employed in cataloguing these specimens, fixing them on tablets, renewing the old provisional labels, and generally in securing them from such damage in the future as they have suffered in the past, so bringing them into a condition for systematic study by specialists.

The important and comparatively recent discovery of fossiliferous beds of Pliocene age by members of this Society in the parish of St. Erth, and our very recent acquisition of a most interesting series of the St. Erth mollusca, for which we are indebted to Mr. A. Bell, F.G.S., has now made it necessary to set apart case No. 1 for the reception of fossil illustrations of the younger geological periods known as Pliocene, Pleistocene, and Recent.

In arranging case No. 1 it has been thought desirable to treat the whole of Cornwall and the western part of Devonshire as geologically one region, and the fossil illustrations have been brought together from various parts of the Museum, where for the most part they had not been hitherto very well displayed. The superior valley deposits and submerged forest beds furnish hazel-nuts and fragments of oak and other woods which do not appear to differ from those now growing. These same beds have furnished an ancient shovel of oak, and examples of such well-known shells as *Scrobicularia*, *Cardium*, *Littorina*, *Pholas*, and *Teredo*.

Following these examples, we have a part of the valuable and historic find of mammalian remains from the Happy Union Tin Stream Works, which was presented to the Society by Mr. J. W. Colenso[1] in the year 1829. It includes

[1] Colenso, *Trans. R.G.S. Corn.*, iv., p. 29 (read Oct., 1829).

bones of a great species of ox (*Bos primigenius?*), of an extinct species of whale (*Eschrictius robustus*),[1] and part of a deer's antler impregnated with tin oxide,[2] also the upper part of a human skull which appears to be similarly impregnated.[3]

Following these are placed a series of teeth and bones from the Plymouth caves, comprising those of the wolf, fox, roedeer, red deer, horse, hog, hare, rabbit, etc., together with sundry bones of

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[1] Flower, "On the Bones of a Whale found at Pentuan," *Trans. R.G.S. Corn.*, ix., p. 144. The larger whale-bones will be seen at the foot of the staircase.

[2] Collins, *Trans. R.G.S. Corn.*, x., p. 98.

[3] These fossils were found in a bed of sea-sand 20 feet in thickness, which rested on a bed of silt, and was separated from the "tin ground" by about 12 feet of silt, together with several thin intercalations of vegetable *débris*. It is evidently, therefore, a matter of considerable interest to find that the bones are impregnated with tin oxide. This skull has not been analysed, but its weight suggests that it may be stanniferous, like the antler. In the year 1887, Mr. W. Ambrose Taylor, then Curator of the Society's Museum, reported thereon as follows :—

"I have to-day determined the specific gravity of the portion of 'stannified' skull from Pentuan.

Weight in air = 8203·125 grains
Weight in water = 4081·500 grains
} Specific gravity = 1·99026.

"This portion of skull consists entirely of the part which contained the brain : all the facial portion, jaws, teeth, etc., are missing; and, so far as I am aware, the Museum has never possessed them.

"For comparison, I have also determined the specific gravity of a portion of a skull which appears to be in a normal condition, except that it has been bleached almost as white as ivory, and has a very smooth, polished, enamel-like surface.

Weight in air = 3670·75 grains
Weight in water = 1559·00 grains
} Specific gravity = 1·73825.

"This portion of skull consists of the facial portion, with three molar teeth *in situ*. All the other tooth-sockets are empty.

"I believe the specific gravities I have given are fairly accurate :

birds not yet determined, all of which were presented in the year 1887 by Mr. R. N. Worth.[1]

Next we have the valuable and historic series of bones and teeth from Kent's Cavern presented by the Rev. J. M. McEnery in 1829. This includes a number of fragments of rhinoceros bones (many of which have been gnawed by hyenas), also teeth of the rhinoceros, hyena, horse, and deer. There is also a cast of the rare tooth of the extinct *Machairodus latidens* found long after in the same cave, and presented by Mr. Pengelly in 1887.

Following these Pleistocene fossils, I have placed the interesting collection of mollusca from the Pliocene beds of St. Erth recently presented by Mr. Bell, and well described and illustrated in his paper read here on the 9th November, 1897.[2] Of course the series is very incomplete, as many of the species are exceedingly rare; thus of the 188 univalves we have twenty-eight, and of the

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but it is right I should tell you that I had to determine them by an ordinary grocer's balance, not very sensitive; and I cannot answer for the accuracy of the weights used. I, however, did the best I could: all weighings were from the same end of the beam; the same weights were used as far as could be; and the skulls were immersed in the same water, which had been previously boiled and allowed to go cold. Of course, the decimal parts of grains are derived from reducing ounces, etc., to the lower denomination. The balance would certainly not indicate anything less than three or four grains when loaded with a skull and weights."

[1] See Worth, "Notes on Some Teeth from a Stonehouse Bone-cave," *Trans. R.G.S. Corn.*, x., p. 165.

[2] See Bell, "On the Pliocene Shell-beds of St. Erth," *Trans. R.G.S. Corn.*, xi., p. 3, and Plates I.–III.

sixty-two bivalves we have eleven only. Still it is a most interesting collection, and it will no doubt in time attract to itself examples of the missing species.

It would be well if we could follow up this series of Pliocene mollusca with some examples of the Miocene flora from Bovey Tracey. I mention this here in the hope that some of our influential members may be able to procure such a series for our Museum.

With case No. 2 we begin the series of local palæozoic fossils. First we have a number of Lower Carboniferous plant-remains from Bude, but these are very imperfect, and it is much to be desired that the collection should be augmented. Here, too, I have placed two or three imperfect specimens from the Lower Devonians near Fowey, collected half a century ago by Mr. Peach. Following these are a few examples of the radiolarian cherts, lately discovered by Mr. Howard Fox;[1] then come two or three not very good specimens of the protozoic *Sphæronites* and *Caunopora*. Here, too, I have placed the specimens of graptolites "from near Porthalla," presented by Mr. F. J. Stephens, which have been named and illustrated by Mr. Lapworth, and the rest of the case is occupied by part of the Society's collection of social corals (Actinozoa), mostly of the genera *Pleurodictyum* and *Favosites*.

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[1] *Trans. R.G.S. Corn.*, xii., p. 39, read Nov. 8th, 1896.

In case No. 3 I have placed the curious series of organisms hitherto named *Cladochonus*, and supposed to be social corals, but which require much further study before their affinities can be certainly determined. Then we have the Society's fine series (nearly 100 specimens) of the solitary coral *Petraia*, also one specimen of *Lindstrœmia*, and several examples of *Microcyclas* and *Strombodes*. Following these there are many examples of the polyzoans known as *Glauconome*, *Fenestella*, *Retepora*, etc.

In case 4 will be found a fine series of palæozoic Brachiopoda of the families *Lingulidæ*, *Productidæ*, and *Orthidæ*.

(*c*) GENERAL REMARKS. 1. I desire to take this opportunity of repeating what I have said before as to the naming of the Cornish palæozoic fossils; viz., that so far it is to a large extent provisional, and often not even consistent, for until all the specimens could be mounted, displayed, and submitted to specialists, I have thought it better whenever a specimen bore a name to retain it, or to reproduce it unless it was obviously misleading or altogether wrong.

2. The Society is much indebted to Mr. Upfield Green, F.G.S., for the gift of a considerable number of interesting specimens at various times. Among the most recent of his gifts I may mention the following:—

CORNISH SPECIMENS.

1503	*Rhynchonella Pengelliana* . .	Fowey.
1511	„ „ . .	„
1515	„ *Stricklandi* . .	„
1506	*Orthis circularis* . . .	„
1524	„ *striatula* . . .	Pridmouth.
1513	*Streptorhynchus gigas* . .	Fowey.
1509	*Spirifera hysterica* . . .	„
1512	„ *paradoxus* . . .	„
1521	„ „ . . .	„
1522	„ „ . . .	„
1526	„ *primæva* . . .	Pridmouth.
1510	*Athyris undata* . . .	Fowey.
1514	„ „ . . .	„
1528	*Pterinea lamellosa* . . .	Pridmouth.
1508	„ *costata* . . .	Fowey.
1520	*Ctenocrinus rhenanus* or *stellifer?*	Fowey, etc.
1505	*Petraia celtica?* . . .	Trelawn.
1519	*Microcyclas simplex* . . .	Bedruthen.

Also the following:—

GERMAN SPECIMENS (for comparison).

1504	*Athyris undata* . . .	Nassau.
1507	*Streptorhynchus gigas* . .	Seifen.
1530	„ *umbraculam* .	Teufels Loch.
1516	*Atrypa aspera* . . .	Niederehe.
1517	*Pterinea costata* . . .	Seifen.
1518	*Phacops fecundus* (*Kayser*) . .	Nassau.
1523	„ „ . . .	„

The Society is also indebted to Mr. Green for the skilful excavation of one of the specimens of *Pteraspis cornubicus* from Lantivet Bay which was collected and presented by Mr. Peach about fifty years ago. Mr. A. Smith-Woodward, F.G.S.,

F.L.S., of the British Museum, has been kind enough to examine this specimen, to compare it with others in the British Museum, and to contribute a note thereon for this meeting. It is interesting to learn that our fish was much larger than any of his fellows yet discovered.

Mr. Green also sends for exhibition two specimens of a very peculiar organism which he has named *Nereitopsis cornubicus*, and has prepared a drawing and short note thereon for our *Transactions;* also in due time he has promised to present the specimens to the Society.

RECENT DISCOVERIES OF GOLD IN WEST CORNWALL.

By Francis J. Stephens, F.G.S.

(Read November 8th, 18,8.)

INTRODUCTION.

Considerable attention has recently been directed to the possibility of gold existing in payable quantities in West Cornwall. In the last Report of the Royal Cornwall Polytechnic Society, we have a paper by Captain William Hambly, of Redruth, upon the subject.[1] Both Mr. J. H. Collins[2] and Mr. Richard Pearce,[3] authorities of great repute, have also recently expressed opinions on the subject. Some discoveries within the past year have again proved the undoubted existence of gold west of Truro, but unfortunately the percentage at each locality has not yet proved of sufficient value to warrant mining operations.

Some account of the geological position of these gold finds may, however, be of interest.

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[1] Hambly, "The Conglomerates of Cornwall," *R C.P.S. Rep.*, 1897.

[2] Collins, "Origin of Ore Deposits in West of England," *Trans. R.I.C.*, 1895.

[3] Pearce, *Trans. R.I.C.*, 1896.

LITERATURE OF THE SUBJECT.

Long ago Sir Roderick Murchison[1] suggested that the rocks of Cornwall might eventually be proved to be gold-bearing.

The tin streams of Cornwall have long been known to produce gold in association with tin gravel, not only free prills of gold, but pieces of quartz containing free gold. The parishes of St. Stephen's and the Camon valley have in times past proved especially rich. Specimens are to be found in the Museum of the Royal Institution of Cornwall.[2]

Mr. Arthur Dean[3] was, however, the first writer to call attention to the fact that gold certainly did exist in Cornwall. He found the metal occurring in the main lode[4] of the Great Dowgas Mine, near St. Austell. This lode was in intimate association with a large and porphyritic elvan. He mentions also the fact that the lead and copper lodes between Falmouth and the Lizard mostly contain gold; while, most interesting of all, he states that a few miles from Falmouth is a large lode containing from 1½ to 2 ozs. per ton throughout the mass.

Unfortunately for us, Mr. Dean does not indicate the exact position of this lode, which is tantalising.

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[1] Murchison, *Siluria.*

[2] Hunt, "British Mining"; Henwood, Notes in various Papers, *R.I.C.*

[3] Dean, "Gold in Cornwall," *Rep. Miners' Assoc. Corn.*, 1865.

[4] 7½ dwts. per ton.

The lode was of white quartz (spar) with lead, some copper and iron pyrites.

Mr. Dean also mentioned the fact that in the British Museum there is, or was, a specimen of visible gold in quartz and chlorite slate from Cornwall.

Mr. S. R. Pattison in 1865 wrote a paper for this Society, in which he describes a very ferruginous quartz reef north of Rough Tor, and not far from Camelford. This reef contained an appreciable quantity of gold. And Captain John Garby still earlier found gold in a large cross-course at Wheal Sparnon, south of Redruth. This was free gold on quartz, and came from a considerable depth.

Mr. Whitley mentions the existence of gold in the raised beach near Newquay in 1864. The proportion was ½ oz. per ton.

Mr. Collins, in his recent valuable paper, speaks of the existence of gold in various localities.

Lastly, we have Captain Hambly's able paper on the subject a year ago, in which he states definitely that he has found gold in the sand of the Manaccan river, and suggests the existence of gold in the breccias and conglomerates of Caermenow and the Nare Head and the gravels of Crousa Downs.

Quite recently—in September, 1898—Captain Hambly has found gold in the Gwennap district, and notably at Wheal Gorland gossan, a little north of St. Day. The result of an assay from this place gave—gold 6 dwts., silver 2 dwts., and 13 per cent. tungstic acid, or = 15·5 per cent. wolfram.

RECENT DISCOVERIES OF GOLD IN CORNWALL.

Acting upon Captain Hambly's suggestive paper, the writer has recently made some assays of the material from the places indicated by him, with the result that the Nare Head material showed no gold, traces only in the Caermenow breccia; while the bed of the Manaccan stream from two or three places showed a considerable quantity of gold.

A little below Manaccan village, on the road leading from that place to the Lizard, several veins of quartz appear in the roadside. These are very ferruginous, and the assay shows traces of the precious metal.

A few yards lower down is an old adit which has been driven into the hillside some distance on a large quartz lode. A winze in the bottom of this level takes one into a still lower level. This has been driven westward nearly 50 fathoms on the course of the lode. It is hard to say which metal the ancient workers sought after, as there are no signs of lead, copper, or blende. An assay of the material showed a low percentage of silver and traces of gold.

Near Falmouth, on the Roscarrack estate, is an old quarry which contains a quartz reef associated with a black siliceous rock, which in places assumes a cherty character. Last spring the writer was surprised to find in this reef a few small flakes of free gold, and since that time free gold has been

detected in the same reef by Mr. R. J. Connock and Captain Hambly.

The lode contains iron pyrites, galena, and blende, and these minerals have also been found to carry gold. Some assays ran over an ounce to the ton, but as yet the result of bulk assays has not been such as to warrant the beginning of mining operations.

Mr. Hutcheon, of Camborne, has this year discovered gold in the black portion of the raised beaches near Godrevy, on the north coast of Cornwall. This black, sandy material contains 13 per cent. of oxide of manganese, while the gold runs in the best assays something over ½ dwt. per ton.

Similar material from the raised beaches of Falmouth and Gerrans Bay gave the same results. In the valley of the Red river, near Gwithian, a mass of grey siliceous rock of schistose character has been worked for road material. This rock is traversed by two sets of joints at right angles to each other. These joints are filled with black and dusty oxide of manganese, which contains in its turn a small proportion of gold.

Early in this year some of the mining students at Camborne made an interesting discovery of gold-bearing quartz on the North Cliffs, not far from a place known as Hell's Mouth. The original discoverer was Mr. Allan Archer. The quartz occurs in large lenticular masses and veins, is very drusy, and contains a considerable proportion of green and decomposed chlorite. This latter contains

gold, but occasional specks and spangles of free gold are to be seen. Assays have gone as high as 1 oz. per ton.

GEOLOGY OF DISTRICT NORTH OF CAMBORNE.

Standing on the North Cliffs and looking inland, one observes three miles inland the granite hills of Carn Brea, Carn Entral, and Camborne Beacon Hill. The Camborne and Illogan mining district may be said to lie between the Red river and these hills. The country may be described as two plateaus separated from each other by the lower part of the Red river valley and the valley passing up towards Tehidy. The mining district is traversed by several deep cross-valleys along the strike of various cross-courses.

The killas or clay-slate of Dolcoath, Camborne, etc., is generally deep blue in colour, very silky, and traversed by innumerable joints. It is sometimes, but rarely, hornblendic.

The Setons, Roskear, and Tolgus mines are characterised by the occurrence of greenstones, which, in connection with the lodes, have yielded enormous quantities of copper ore. Messrs. Allport[1] and J. A. Phillips[2] have described these greenstones as being probably altered ash-beds or ashy slates, which have been much changed in character by heat, pressure, and infiltration. They are intensely hard, deep blue or green, and sometimes brown

[1] Allport, *Quar Jour. Geo. Soc.*, vol. xxxii.
[2] Phillips, *Quar. Jour. Geo. Soc.*, vols. xxxi., xxxii., xxxiv.

in colour, often very crystalline, and containing hornblende, and rarely crystals of axinite or actinolite.

The rocks lying northward of these "greenstones" alter rapidly in character. From being hard, compact, and almost homogeneous, they become schistose and fissile. Quartz becomes abundant, and everywhere on the fields and moorlands we see angular fragments of this white "spar." The killas nearer the granite is also quartzose, but the quartz is of a dark grey colour and somewhat opaque, rarely chloritic, but often containing oxide of tin or other ores in small quantity.

The white "spar" of the North Cliffs is practically free from metalliferous minerals, and abounds in green and decomposed chlorites. The slate series is sometimes, but not often, micaceous, and chlorite abounds, more especially nearer the sea. The whole country for a distance of some miles may be described as chlorite schist, traversed by innumerable veins and masses of quartz. Here and there we meet with thin bands of fine and coarse grained grits, more especially developed west of Godrevy Headland. Here, too, the slates lose much of their chloritic character, and become blue and glossy, often being micaceous, and containing pyrites in some quantity. A siliceous schist has been opened upon and worked in some places.

The quartz reefs which form such a feature of the district show a singular inconsistency in their continuation, and are exceedingly lenticular. They

appear to traverse the slate series in every direction. Sometimes following for a while the main direction of the strike of the rocks, they are quite as often to be met with following north and south lines of fracture. At one place the observer will note quartz masses cutting diagonally across the strike of the slate; a few yards further on he meets with masses going in an entirely opposite direction. A vein may be seen at one place nearly 10 feet wide; a few fathoms on it has dwindled to as many inches. Looking up at the face of the cliffs, a similar structure is observed in their vertical extension.

The chloritic nature and inclined direction of the slate series have combined to make parts of these cliffs very subject to slips. This in its turn has set up a somewhat cavernous structure amidst the larger masses of quartz. In one place, indeed, a large fissure has been opened as the effect of a great quartz mass slipping bodily away, while several incipient caverns are to be seen near by.

GEOLOGY OF THE COUNTRY NEAR ROSCARRACK.

The granite of the Carn Menellis range extends southward as far as Budock Rocks, near Falmouth. From this place a stream flows through a deep valley to the sea at Maenporth. The lower part of this valley opens out, and contains a layer of poor tin ground beneath a thick deposit of sand and silt.

This Budock-Maenporth valley cuts across the strike of the slate rocks, and affords a good cross-

section. Near the granite the slates are brownish in colour, and full of little spots and clusters of incipient crystals; it is, in fact, a species of *knoten-schiefer*. Southward we meet with a peculiar detrital sort of rock, which is probably an ancient mudstone, or ashy bed, full of small fragments of somewhat similar, perhaps pre-existent, rock. This rock is met with in the Roscarrack quarry. Southward there are hard and compact blue slates near Hard-to-come-by, and near the sea we meet with variegated slates similar to those which abound near Falmouth.

In this valley there are a singular number of quartz reefs or lodes. Below Maenhay, about half a mile south of Budock village, are the outcrop and accumulated erratic blocks of a large quartz reef. This contains carbonate of copper, and spots and patches of blende and galena, with a few rare spots of the beautiful mineral vivianite (phosphate of iron).

The quartz reef containing gold in the Roscarrack quarry has been already described. Half a mile south of this place are the many lodes of the old Pennance Mine, notable from the fact that here Mr. R. Were Fox,[1] the discoverer of the dipping-needle, carried out many of his early experiments on the magnetic properties of mineral veins. These lodes contained a singular variety of minerals: tin,

[1] R. W. Fox, "Electrical Experiments Underground at Pennance Mine," *Phil. Trans.*, xxii.

copper, lead, arsenical pyrites, and blende. The north lode is an immense quartz reef, over 10 feet wide; its outcrop is to be seen on the side of the hill north of Hard-to-come-by. It is a hard, bluish-grey rock, somewhat drusy, and containing iron oxide and chlorite. This material, too, shows traces of gold in the assay.

The lodes of Wheal Clinton, Swanpool, Newporth, Pennance, and Wheal Anna Maria, near Portnavis, all contain more or less blende, galena, and associated ores. The writer has assayed samples of all these, and found them to contain a considerable proportion of silver with generally a little gold; for instance, some of the Swanpool galena ran nearly 30 ozs. of silver to the ton, and contained over 5 dwts. of gold in the silver.

GEOLOGY OF THE MANACCAN DISTRICT.

No district in Cornwall has received more attention from geologists than the Meneage and Lizard areas, but few of them appear to have noted the extremely quartzose character of the slate country between the Helford and Manaccan rivers. It is by no means unlike the district north of Camborne, but the slates are apparently less chloritic, and contain a considerable proportion of mica in some places, and are ordinary clay-slates in others. The predominating colour is blue or yellow, but the quartz reefs are distinctly yellowish in colour. Here and there are a few bands of fine-grained grit as seen near St. Anthony.

Southward we meet with the breccias and conglomerates of Caermenow, etc., while beyond this is the Ordovician area, with its quartzites and radiolarian cherts.

Mr. Collins[1] describes the rocks immediately south of the Helford river as grey siliceous schists, with a few beds of inferior blue roofing slates, some soft sandy beds passing into a not very coarse conglomerate, and one or two beds of hard quartzite. The dip is S.S.E., and the upper beds, if anything, are more siliceous than the lower ones.

The breccias of Caermenow[2] and Gillan Creek consist of rounded and angular masses of different rocks, some large, some small, cemented together by a reddish sandy material, sometimes containing iron pyrites, but mostly oxide of iron mixed with clay and sand. This is supposed to be of volcanic origin more or less. The cementing material is slightly auriferous.

RAISED BEACHES.

The raised beaches around our coasts will be very often noticed to consist at their base of a black layer of sandy clayey material. This is very often hard and compact, but it is rarely to be noticed except at the base of the raised beaches. Near Rosemullion Point I have noticed two layers about three feet apart, but not elsewhere.

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[1] Collins, "Geological Structure of Northern Part of Meneage," *Trans. R.G.S. Corn.*, 1879.

[2] Fox and Somervail, "Occurrence of Volcanic Tuffs, etc., in the Meneage District," *Trans. R.G.S. Corn.*, 1884.

This black sand contains a considerable proportion of oxide of manganese and a small percentage of gold. Mr. Hutcheon, of Camborne, has kindly supplied the writer with the following remarks on the subject:—

He thinks that "during some period since the deposition of the raised beaches swampy conditions prevailed, and that the manganese was due to this. The gold, however, is not so easily explained, although most manganese deposits do contain a little gold. It does not, however, follow that the swampy conditions prevailed during the deposition of the raised beaches. They may have been subsequent, and possibly the filling in of the manganiferous joints of the siliceous rock in the Gwithian valley may also be due to this cause in part."

GEOLOGY OF KNOWN BRITISH AURIFEROUS LOCALITIES.

(SCOTLAND.)

Gold has been found in Sutherlandshire, Caithness, and again amongst the Lead Hills of Southern Scotland, near Nithsdale.

The Sutherlandshire deposits consist of ferruginous sand and gravels, with boulders of considerable size. These beds underlie the peat moss and stratified sand and clay. They are probably of late Glacial age or early Post-glacial, and bear a striking resemblance both in age and appearance to the raised beach deposits of Cornwall and

elsewhere. Beneath the auriferous gravels lie the up-tilted edges of Lower Silurian and earlier rocks full of quartzites and quartz reefs. Some of these are hornblendic and pyritiferous. Further up the valleys are mountains of eruptive and metamorphic granite.[1]

Professor Ramsay held that the auriferous gravels had been torn in the first instance from the granite highlands and spread over the valley beds by glacial action, and that Post-glacial action, far more quiescent in its character, had sifted or jigged, as it were, the gold to its present position at the base of the mass.[2]

Sir Roderick Murchison[2] thought that the probable source of the Sutherlandshire auriferous drift was to be found amongst the chloritic micaceous flags and schists which overlaid the Lower Silurian rocks.

A certain analogy will be found between the rocks of Sutherlandshire and those of the northern Meneage district.

Mr. Lauder Lindsay, in a paper written in 1868, describes the Scottish gold districts amidst the Lead Hills; Calvert also described all the Scotch, Irish, and Welsh gold fields much earlier. The gold region of Lanarkshire was situated on the high moorlands from which converge the Clyde, Nith, Tweed, and Annan valleys.

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[1] Joass, "Sutherland Gold Field," *Q.J.G.S.*, 1869.

[2] Murchison and Ramsay opinions cited in same paper; Lauder Lindsay, "Gold Fields of Scotland," *Trans. R.G.S., Ireland*, 1868; Calvert, "Gold Rocks of Great Britain and Ireland."

Here, too, gold was found in gravelly clay, corresponding to our Cornish "Head," and, like the "Head," it is of Post-glacial age.

At the time Lindsay wrote the watershed of these four great valleys belonged to what was then known as the Greywacke system of Murchison and others. Recently, however, these rocks have been proved to be Lower Silurian or Ordovician.

Gold was found also in Perthshire and Inverness, again in connection with chloritic rocks of Ordovician age, and in close connection, as in Lanarkshire, with galena.

(IRELAND.)

Ireland, like Scotland, was said long ago to have been rich in gold, in those far-away and barbaric days "when Malachi wore the collar of gold which he won from the bold invader." It was said to have had mines of native gold, and there are many other tales of auriferous character.

In Wicklow it occurs in the great iron pyrites lode of the Ovoca mines.[1] A great discovery of detrital gold was made near these mines in 1796. It was apparently derived from ferruginous quartz ridges, that traversed the granite and metamorphic rocks of the district.

A quartz vein in Wicklow, near Bray Head, and in Cambrian green and grey grits and slates, was found to be auriferous in 1882.[2]

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[1] Argall, "Gold in Wicklow Mines," *Trans. R.G.S., Ireland*, 1865.
[2] Smythe, "Mines of Wicklow," *Records School of Mines.*

Some galena and pyrites ores, besides those of Wicklow, were found to be auriferous years ago.

Drift gold similar to the Scottish deposits has been met with in detritus derived from Silurian mica slates with some igneous rocks.

Other placer deposits derived from Silurian rocks and quartz reefs occur at Croghan Kinshelagh, in Wicklow.[1]

Hitherto we have dealt mostly with gold in detrital deposits, but the Welsh gold mines were for the most on auriferous reefs.[2]

(WALES.)

The gold region about Dolgelly, in Merionethshire, was worked by the Romans. Mr. Arthur Dean,[3] in 1844, recognised the auriferous character of the mineral reefs. At Cwmeisen he found on the *débris* heaps of the lead mines fragments of ore that contained 7 ozs. per ton. Afterwards many of the quartz veins and lead and copper lodes were found to be full of gold. Vigra and Clogan Mine, started first as a copper mine, produced gold to the value of £36,000.[4]

The strata in which these gold reefs occur belong to the intermediate beds between the Cambrian and Ordovician series where the Lingula flags are

[1] Kinahan, "Occurrence and Working of Gold in Ireland," *Trans. R.G.S. Ireland*, 1884.

[2] Mr. J. P. O'Reilly, in 1892, made several assays of metalliferous material, etc., from the neighbourhood of Dublin, with the result that gold in appreciable quantity was found in quartz containing iron pyrites, from quartz reefs in Silurian and from quartz reefs in clay slate. "Notes on some Assays for Gold," *Journ. Proc. R. Dublin Soc.*, 1892.

[3] *Lead Mines Assay Report*, 1844. [4] Morrison, *Siluria*.

inverted on the grits and quartzites of the latter. They consist of talcose and chloritic slates. Iron and copper pyrites are abundant both in the slates and the lodes. These lodes are traversed by comparatively barren east and west veins, which at the intersections are often rich in gold. At least a dozen mines were started between 1856 and 1865, and a considerable quantity of gold was returned.

Near Strata Florida, at Gogofau, gold was worked long ago from quartz reefs in rocks of Arenig age. Both at Dolgelly and Gogofau, as well as at the more recent discovery made by Mr. Pritchard Morgan, greenstones or diorites are always to be met with near at hand.

The Morgan mines near Llandovery are in rocks of Bala age. Here, too, the quartz reefs were full of auriferous iron pyrites.[1] These pyrites contain enough gold to pay costs of working. Whenever free gold is met with the reef is mined at a profit.

Alluvial gold has also been met with in Wales, but by no means in the rich proportion of Scotland and Ireland.

(DEVONSHIRE.)

At North Molton, near Barnstaple, gold has been found associated with the lode stuff of an old iron and silver lead mine. These Poltimore mines are in rocks of Upper Devonian age. The gold is to be seen occasionally as spangles in the gossany backs of the large reef, which is very ochreous, and contains much cellular quartz.

[1] Davies, *Metalliferous Minerals and Mining.*

CONCLUSION.

It is improbable that any of these richer discoveries are likely to be ever eclipsed by the auriferous deposits of Cornwall, yet it will be noticed that there is a very general resemblance between all these districts. They all occur in or near rocks of great antiquity; they all have eruptive rocks traversing the clay slates; and—with very few exceptions, they have all proved to be unprofitable undertakings.[1] Yet, although these Cornish discoveries have been proved to be of little value hitherto, the fact of so many auriferous localities having been found in one year shows how widespread the precious metal must be.

A systematic research undertaken by private individuals well equipped for the purpose might result in profitable discoveries. Our county abounds in quartz veins and reefs. The geological formation is eminently a favourable one, and enough has been done to show that gold does exist in many unlikely places.

We must remember that any localities where visible gold is to be seen must be exceedingly rich.

Often apparently barren quartz yields large proportions of gold, and it is quite possible that here and there quartz veins passed and repassed many times a day are in reality sufficiently auriferous to well pay the lucky discoverer.

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[1] Pattison, "A Visit to the Poltimore Mines, North Devon," *Trans. R.G.S. Corn.*, 1863.

THE LOWER PALÆOZOIC ROCKS OF THE SOUTH OF SCOTLAND, VIEWED IN CONNECTION WITH THE LOWER PALÆOZOIC ROCKS OF CORNWALL.

By J. Bastian Hill, R.N. (H.M. Geological Survey).

(Read November 8th, 1898.)

The region of Cornwall and Devon is closely linked with the early history of British geology, for it was here that Sir Henry de la Beche first began the detailed examination of rock-formations in the field which ultimately paved the way for the Geological Survey of the United Kingdom. He realised that the delineation of the various rock-masses on the Ordnance Survey maps, then available, on the scale of 1 inch to a mile, the determination of the geological structure of the region, and the tracing of the metalliferous veins and other mineral resources might be of great economic value, and at the same time promote the interests of the science.

These broad principles, so clearly grasped and strenuously enforced by that distinguished investigator, have since that time guided the

officers of the Geological Survey in their prosecution of the national work.

All those who are interested in English geology are familiar with the classic work of De la Beche, viz., his *Report on Cornwall, Devon, and West Somerset*, in which he gives abundant proofs of his brilliant powers as an observer in the field, and likewise of his artistic power in faithfully depicting what he saw. It matters not whether we turn to his observations on mineral veins, to the evidence which he adduced in support of recent changes in the relative levels of land and sea, to his interpretation of the structure of the south-western counties, or to the striking proofs which he adduced of the metamorphism of the surrounding rocks by the intrusive granite masses, his observations on these and other phenomena place him in the front rank of British geologists during this century. But since the appearance of De la Beche's report, and since the publication of the Geological Survey maps of the south-western counties, the science has advanced with marvellous rapidity. Many valuable discoveries have been made in Cornwall within recent years, some of which may be of special importance in fixing the horizon of the Lower Palæozoic rocks of part of the county. Indeed, the discovery of the radiolarian cherts with the associated volcanic rocks by Mr. Howard Fox, and the numerous papers by Messrs. Bonney, Teall, MacMahon, and others on the crystalline rocks

of the Lizard, have aroused the attention of the followers of the science both at home and abroad.

It is natural, therefore, that a demand should have arisen for the resurvey of the county, and in the prosecution of this work the district in the neighbourhood of Falmouth has meanwhile been assigned to me by the Director-General. Considering the short time that I have been working in the region, I do not presume on this occasion to offer any remarks on the structure of the Falmouth district based on my own observations in the field. The area which has been traversed by me in detail has been too limited to enable me to speak with any confidence on the geological questions involved. But when you invited me to read a paper to the members of this Society, I thought that it might be interesting to you, as it has been profitable to myself, to compare certain prominent geological features of the southern uplands of Scotland with those of Cornwall. By this method I might indicate certain analogies between the geological phenomena of these widely separated areas, and at the same time suggest certain lines of investigation which might guide us in the future examination of the region.

THE SOUTHERN UPLANDS OF SCOTLAND.

Key to the Geological Structure of the Chain. In the history of Scottish geology, few more signal

triumphs have been recorded than that of Professor Lapworth in his discovery of the key to the geological structure of that complicated region. After years of prolonged investigation in the field, he arrived at the conclusion that by means of the vertical distribution of the graptolites it is possible to work out the order of succession of the strata and to unravel their structure. He showed that certain specific forms are confined to certain definite horizons, which are consequently of the highest value in fixing the age of the beds in which they occur. He further showed that though these organisms are mainly confined to black shale bands, which are traceable across the uplands, yet as the observer proceeds northwards and westwards from Moffat towards the Girvan region the black shales gradually undergo lithological changes and are intercalated in other sediments such as flagstones, greywackes, grits, conglomerates, and limestones. But, notwithstanding these lithological changes, Professor Lapworth showed that many of the zonal graptolites are recognisable even in the Girvan region, whereby he was able to correlate the rocks of Girvan with those of the central Moffat area. His researches are now so well known to geologists that it will be sufficient for my purpose if I indicate very briefly his main divisions in the Moffat region, where he first ascertained the true order of succession. The Moffat series, consisting mainly of black shales, clays, mudstones, and similar fine sediments, are

divisible into three groups in the following descending order:—

	CHARACTERISTIC GRAPTOLITES.
Birkhill Group = Llandovery =	*Rastrites maximus*, *Monograptus spinigerus*, *Monograptus Clingani*, *Monograptus gregarius*, *Diplograptus vesiculosus*, *Diplograptus acuminatus*, &c.
Hartfell Group = Caradoc =	*Dicellograptus anceps*, *Pleurograptus linearis*, *Dicranograptus Clingani*, *Climacograptus Wilsoni*, &c.
Glenkiln Group = Upper Llandeilo =	*Didymograptus superstes*, *Cœnograptus gracilis*, *Dicellograptus sextans*, *Diplograptus mucronatus*, &c.

These various black shale bands, which collectively do not exceed 300 feet in thickness, form a series of anticlines in the central portion of the uplands, traceable for several hundred yards, or it may be for a few miles. Frequently the arches are inverted, and they are likewise traversed by normal and reversed faults. But in all cases where the rocks have not undergone contact metamorphism, and where the fossils have not been distorted by cleavage, it is possible to prove beyond all doubt the anticlinal arrangement of the strata; the members of the lowest group occurring in the centre of the folds, while the higher zones follow in normal order.

These black shale arches in the central Moffat

region come to the surface in the midst of strata of Tarannon age, consisting of coarse grits, conglomerates, greywackes, and shales, which along the southern margin of the uplands pass conformably upwards into Wenlock and Ludlow rocks, with their characteristic fossils.

When, however, we pass from Moffat north-westwards to Girvan, the fine sediments of the Moffat region, as already indicated, gradually change their lithological characters, and are interleaved in limestones, sandstones, greywackes, and flagstones, which in the Girvan area attain a thickness of several thousand feet. There we find the Moffat series represented by a highly fossiliferous series of sediments which must have been deposited at no great distance from the old Silurian land surface, and in some instances along the shore. These are richly charged with corals, echinoderms, crustacea, polyzoa, brachiopods, gasteropods, and other marine organisms.

The application of the zonal method of mapping to the southern uplands of Scotland revealed to Professor Lapworth the striking fact that the members of the Moffat series come to the surface again and again by means of innumerable folds. Indeed, over a great part of that tableland the same zones are repeated for miles, proving beyond all doubt the extraordinary reduplication of the strata.

LOWER LLANDEILO AND ARENIG ZONE OF RADIOLARIAN CHERTS.

In the course of the revision of the Silurian rocks of the southern uplands by my colleagues Messrs. Peach and Horne, with the assistance of Mr. Macconochie, which began in 1888 after the publication of Mr. Lapworth's researches, an important zone of radiolarian cherts was detected, which, together with the graptolites, has been of great service in working out the structure of the northern portion of the tableland.

From the researches of Dr. Hinde, in whose hands the collection of cherts was placed for examination, it appears that he identified twenty-three new species of radiolaria. He had no difficulty in arriving at the conclusion that the chert is a genuine radiolarian rock, due to the accumulation of the tests of radiolaria.

ARENIG VOLCANIC ROCKS.

My colleagues likewise found that in the district of Abington, near the northern margin of the uplands, these cherts are associated with volcanic rocks, lavas, agglomerates, and tuffs, accompanied in some instances by intrusive dolerites. In that region they ascertained that the volcanic rocks occupy the centre of the anticlines, being followed in normal order by the radiolarian cherts; the latter being succeeded by the Glenkiln black shales, charged with the characteristic Glenkiln graptolites

of the Moffat region (Upper Llandeilo). It was further found that between the zone of radiolarian cherts and the underlying volcanic rocks there is a thin band of mudstones richly charged with hingeless brachiopods, belonging to the genera *Acrothele*, *Acrotreta*, *Lingula*, *Lingulella*, &c.

These mudstones, in one section in the Abington area, are underlain by a thin seam of black shale, which rests directly on the volcanic rocks, containing the following Arenig graptolites: *Tetragraptus fruticosus*, *Tetragraptus quadribrachiatus*, together with a phyllopod crustacean, *Caryocaris Wrighti*.

Here, then, in the northern portion of the Silurian tableland of the south of Scotland, there is evidence to prove that the zone of radiolarian cherts, which does not exceed 100 feet in thickness, is overlain by graptolite shales of Upper Llandeilo age and rests on a thin seam of black shales of Arenig age. These cherts, though of no great thickness, represent a vast interval of time, being partly of Upper Arenig and partly of Lower Llandeilo age.

All over the northern portion of the tableland these Arenig volcanic rocks are exposed at the surface along the crests of innumerable anticlines, as may be seen by referring to the last edition of the geological map of Scotland by the Director-General of the Geological Survey. Indeed, where denudation has proceeded far enough to expose this horizon, the Arenig volcanic rocks are invariably found. These exposures throughout the

uplands are as a rule extremely limited, being traceable only for a short distance as narrow lenticular masses in the midst of the radiolarian cherts. By far the largest and most important of these Arenig volcanic rocks occurs in the Girvan and Ballantrae region in Ayrshire, where their igneous character was first recognised by Professor Bonney. They have recently been mapped by my colleagues Messrs. Peach and Horne, and a revised edition of the Girvan sheet is just being issued by the Survey. The results of that revision, together with certain observations of the Director-General, are summarised in the first volume of his work on *The Ancient Volcanoes of Great Britain*, and in the annual reports by the Director-General.

ARENIG VOLCANIC ROCKS OF GIRVAN AND BALLANTRAE.

There are many features connected with the history of the Arenig volcanic rocks of the Ballantrae region in Ayrshire, which are of special interest to us. It may be sufficient for my present purpose if I allude to the following points :—

Lithological Characters. First, as to the lithological characters of the volcanic series, which include both lavas, tuffs, and volcanic agglomerates. By Mr. Teall the lavas have been grouped as diabases and diabase porphyrites, the former being fine-grained, with numerous amygdules, while the

latter are porphyritic, containing large crystals of more or less altered plagioclase. Their characteristic feature in the field is the peculiar sack-like or pillow-shaped structure, which is remarkably conspicuous on the shore section to the north and south of Ballantrae. The tuffs and agglomerates which are associated with these lavas are of varied types. One is a coarse agglomerate containing large crystals of plagioclase and augite in a greenish serpentinous matrix, as if the rock were due to the explosion of some tolerably basic mass of pyroxemic lava. Indeed, as Mr. Teall has shown, this agglomerate closely resembles the agglomerate of Rhobell Fawr, in North Wales. On the shore at Bennane Head the fragmental volcanic rocks are of a somewhat different type, for there the agglomerate contains pieces of radiolarian chert, black shale, and mudstone, together with fragments of lava.

Evidence of Age. Near the top of the volcanic series Professor Lapworth was the first to discover a band of flinty black shales charged with graptolites of middle Arenig facies, and in the course of the revision by the Geological Survey similar graptolites were obtained on a slightly lower horizon in flinty mudstones or tuffs intercalated in the lavas, the following genera being represented: *Tetragraptus*, *Dichograptus*, *Phyllograptus*, *Dendrograptus*, &c. These are associated with various genera of hingeless brachiopods and a phyllopod crustacean.

No less interesting is the fact that the Arenig volcanic rocks of Girvan are overlaid by an important zone of radiolarian cherts, like the Arenig volcanic rocks throughout the rest of the uplands. Indeed, in one important section, viz., at Bennane Head, the radiolarian cherts are interstratified with tuffs, the latter containing blocks of chert with radiolaria. From the occurrence of masses of chert in the tuffs, it would almost appear as if the siliceous ooze had consolidated on the sea floor during pauses in the volcanic activity, and were subsequently disrupted by renewed outbursts of volcanic energy.

The evidence in favour of the Arenig age of the contemporaneous volcanic rocks of Ballantrae may therefore be regarded as conclusive, and it is no less clear that the important zone of radiolarian cherts which there overlies the volcanic series was deposited contemporaneously with some of the tuffs.

The lavas, tuffs, and agglomerates just described are associated in the Girvan region with an important series of intrusive rocks, which appear to be later than the interstratified volcanic material. The most prominent of these plutonic rocks is serpentine, which forms parallel belts, the long axes of which run in a north-east and south-west direction ; that is, parallel to the general system of folding in the region. Long ago Professor Bonney recognised the resemblance between the serpentine of Balhamie Hill, near Ballantrae, and that of the Lizard, a feature which has been subsequently confirmed by Mr. Teall. The serpentine is associated with

olivine-enstatite rocks, with gabbro, which, in some instances, is foliated, with epidiorite, and to a very limited extent with hornblende schists.

In one conspicuous instance, viz., on the Byne Hill, south of Girvan, there is a plutonic mass which partly consists of gabbro and partly of biotite-granite. The transition from the one to the other is somewhat abrupt, but it is not improbable that they may have segregated from one common magma, the acid portion being the product of later consolidation. Finally, reference may be made to a series of dolerite dykes piercing the serpentine, which, along their lines of contact, display chilled margins. These were first recognised by Professor Bonney, who described their microscopic characters, and, in the course of the recent revision by the Geological Survey, these sinuous dykes have been laid down on the map.

Now it is possible to demonstrate that these plutonic rocks in the Girvan and Ballantrae region must be older than Caradoc time, and therefore separated by a vast interval from the great masses of granite of a younger date which gave rise to marked contact metamorphism in the Silurian strata. The evidence on this point is absolutely conclusive, for everywhere to the north of the valley of the Stinchar, at Ballantrae, these volcanic and plutonic rocks are separated by a prominent unconformability from the younger Silurian sediments, comprising Upper Llandeilo, Caradoc, Llandovery, and Tarannon strata.

At the base of this fossiliferous series there is a coarse conglomerate which reposes sometimes on the volcanic and sometimes on the plutonic rocks, and consists largely of detritus derived from the denudation of the volcanic platform. Indeed, as Professor Lapworth clearly recognised, this Benan conglomerate forms the great datum line in attempting to work out the order of succession of the Girvan sedimentary series.

Having now given you a general outline of the evidence bearing on the age and structural relations of the volcanic rocks and overlying strata in the south of Scotland, we may briefly recapitulate the points in the following order :—

(1) The oldest rocks are of volcanic origin, comprising lavas, tuffs, and agglomerates which, in the Ballantrae, New Camnock, and other regions are associated with plutonic masses, including serpentine, gabbro, epidiorite, hornblende-schist, dolerites, and biotite-granite.

(2) The age of this volcanic series is clearly defined by the occurrence of graptolites of Middle Arenig age in flinty mudstones interleaved in the lavas, and in black shales in agglomerates near the top.

(3) Overlying this volcanic horizon there is a prominent zone of radiolarian chert, which is partly of Upper Arenig and partly of Lower Llandeilo age. In the opinion of Dr. Hinde, this is a true deep sea deposit, the accumulation of which necessarily represents a vast interval of time.

(4) The radiolarian zone is overlain throughout the greater portion of the uplands by sediments yielding graptolites of Upper Llandeilo age (Glenkiln).

(5) Owing to the extraordinary compression of the Silurian strata during elevation, the Arenig volcanic rocks and associated cherts are exposed at the surface only along the crests of sharp anticlinal folds.

Before passing from the Lower Palæozoic rocks of Scotland I may take the liberty of making a brief reference to the fact that my colleagues, Messrs. Barrow, Dakyns, and Clough, have detected along the south-eastern margin of the Highlands a narrow belt of strata probably of Arenig age. They have recorded the occurrence of certain sedimentary strata, comprising cherts with radiolaria, black shales, and other materials which are associated with igneous rocks, often highly cleaved. In some instances, however, their lithological characters are determinable, the rocks consisting of dolerites and basalts. No fossils, with the exception of the radiolaria, have as yet been obtained from the black shales; but judging from the resemblance of the cherts and igneous rocks along the Highland border to similar rocks of Arenig age throughout the southern uplands, it is highly probable that the former may be the northern prolongations of the same series of deposits.

Proceeding now to consider the important paper by Messrs. Fox and Teall "On a Radiolarian

Chert from Mullion Island" (*Quarterly Journal of the Geological Society*, vol. xlix., p. 211), it must be admitted that the evidence is highly suggestive. From their description it appears that the dominant rock is of igneous origin, being fine-grained and often highly decomposed, and showing in the field that peculiar sack-like structure so characteristic of the lavas of Ballantrae. Under the microscope "it consists of felspar, augite, iron ores, and secondary products, such as carbonates and chlorite, derived from these minerals. The felspar may occur as porphyritic crystals sparsely scattered through the ground mass, or as long slender microlites forming a constituent of the ground mass. The augite occurs as small grains and microlites, and is sometimes only represented by secondary minerals. Iron ores are comparatively scarce. In structure the rock is more allied to a lava than to an intrusive mass."

From this description given by Mr. Teall it is clear that the lava of Mullion Island resembles some of the Arenig lavas of the south of Scotland.

Turning now to their record of the stratified rocks associated with the lava, the evidence is equally suggestive. They consist of cherts, shales, and limestones occurring in thin strips, which cannot be traced continuously across the island. Of these the chert zone is the most important from the abundance and excellent preservation of the radiolaria. It is associated with shales, and occurs sometimes in thin layers interstratified with the shales,

and sometimes in a nodular form. "The radiolaria may often be observed, with a pocket lens, on the surfaces of cross-joints, but they are most perfectly seen on the upper surfaces of some of the layers, where the shale has been removed by the weather." Except in the better preservation of the radiolaria, this description would apply equally well to the Arenig cherts of the southern uplands.

The shales associated with the cherts have so far proved unfossiliferous, though a careful search has again and again been made. This fact is not at all surprising, for in the numerous sections of the Arenig cherts outside the Girvan area in Scotland the shales or mudstones associated with them have yielded brachiopods at only a few localities, and Arenig graptolites at one locality near Abington. Indeed, it was only after prolonged and careful searching by Mr. Macconochie that this latter locality was discovered.

The Cornish zone, however, has been brought into close relation with the series in which the late Mr. C. W. Peach obtained Silurian fossils. At present, however, there is merely strong presumptive evidence of the Silurian age of the Cornish radiolarian chert and lava. It is obvious, therefore, that a strong effort must be made to ascertain, if possible, the relations between the fossiliferous Silurian rocks and the radiolarian cherts. If this point can be satisfactorily established, an important advance will have been made in the stratigraphy of Cornwall.

Other questions of great interest and importance are associated with the crystalline schists and plutonic masses of the Lizard. Geologists are well aware of the keen controversies which have arisen regarding the origin of the foliated igneous rocks and the relative ages of the serpentine and hornblende-schists. On one hand, Mr. Teall contends that the foliation of the gabbro and the passage of dykes of porphyritic epidiorite into hornblende-schist have been produced by dynamic metamorphism after the consolidation of the rocks from the original magma. In the case of the epidiorite dykes which traverse the hornblende-schist, and themselves pass into hornblende-schist, he produces evidence of the production of cataclastic structure by dynamic movement which is highly suggestive. He shows that the foliation planes wind round the porphyritic felspars, which have often been compressed into lenticular folia. These porphyritic felspars have suffered fracture and distortion by the movement which produced the fluxion structure. He further shows that the lath-shaped felspars of the ground mass, though still recognisable, "have been bent, broken, and converted into a microcrystalline aggregate in which the original form is partially or wholly lost." He points out that in one section the original rock was a dolerite which did not possess parallel structure, for in the midst of the hornblende aggregates he recognises cores of unaltered augite "which polarise as individuals, and are penetrated by lath-shaped sections of

felspar, whereas the hornblende polarises as aggregates, and shows fluxion round the felspars." He concludes, therefore, "that the original rock was a massive ophitic dolerite; that the parallel structure is the result of fluxion due to earth stresses after the consolidation of the augite."

On the other hand, Professor Bonney and General McMahon ascribe the foliation sometimes present in the gabbro to movements when the rock was in a condition of imperfect fluidity, and not to pressure after the consolidation of the rock.

The cleavage of opinion regarding the relative ages of the serpentine and hornblende-schist is equally well marked. Professor Bonney and General McMahon maintain that the hornblendic and granulitic groups were in their present condition when the rock which is now a serpentine was injected, the serpentine being the result of the alteration of some variety of peridotite. They further contend that the granulitic group includes two types of rock, one acid, the other basic, the former being intrusive into the latter, and that, as a result of this increase of temperature or from some other cause, the temperature of the whole mass was so elevated as to permit of movements that gave rise to the finely stratified appearance of the two varieties.

On the other hand, Mr. Teall holds that the serpentine, hornblende-schists, etc., form a banded complex of crystalline foliated rocks the relative ages of which cannot be satisfactorily determined,

but, if there be any difference in age, he is inclined to believe that the serpentine is the earlier of the two.

Professor Bonney, in his paper "On the Serpentine and Associated Igneous Rocks of the Ayrshire Coast" (*Quarterly Journal of the Geological Society*, vol. xxxiv., p. 769), has called attention to the resemblance of some of the plutonic rocks of Ballantrae to those of the Lizard.

In comparing the geological features of the southern uplands with those of Cornwall, there is a further analogy to which attention might be directed, and that is the presence of large masses of granite which have given rise to prominent contact metamorphism.

Mr. Teall has shown that the various granite masses and their apophyses, which occur chiefly in the south-west of Scotland, belong to one petrographical province. They range from hyperites, which represent the most basic form of the original magma now visible, to biotite-granites or granitites. In one instance, along the eastern slope of Criffel, the granite is foliated along the margin of the mass, a structure which is evidently due to dynamic movement; for the massive granite, together with the later acid veins, have been foliated in one common direction.

These granite masses must be younger than Upper Silurian time and older than the Upper Old Red Sandstone and Lower Carboniferous strata, for they pierce the Upper Silurian rocks, while

pebbles of granite and granitic detritus occur in the conglomerates and sandstones of Upper Old Red and Lower Carboniferous age. Amongst the instances of contact metamorphism produced by these granite masses, perhaps the most remarkable are those described by Miss Gardiner along the margin of the new Galloway granite, where the Silurian greywackes are converted into Sillimanite gneiss, resembling the Sillimanite gneiss of the Eastern Highlands.

The granite bosses of Cornwall and Devon, as De la Beche long ago pointed out, occur among younger rocks as they pierce Devonian and Carboniferous strata.

SUPPLEMENTARY NOTES ON THE CORNISH RADIOLARIAN CHERTS AND DEVONIAN FOSSILS.

By Howard Fox, F.G.S.

(Read November 8th, 1898.)

Since the publication of the paper on the Radiolarian Cherts of Cornwall in your *Transactions* for 1895,[1] a few fresh exposures have been discovered.

Mr. F. J. Stephens has recorded[2] the occurrence of thin beds of chert or cherty shale showing under the microscope casts of radiolaria both north and south of Penryn Creek. This forms a valuable addition to our former knowledge.

Some new exposures of radiolarian chert *in situ* have been observed by myself.

CHYPONS.

About one mile north by east of Mullion Church the public road bridges a stream which, rising in Bonython, runs through the beautiful grounds of Bochym and then passes through

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[1] Vol. xii., part 1, pp. 39–70.

[2] *Rep. R. Corn. Polytechnic Soc.*, 1897, pp. 104–111.

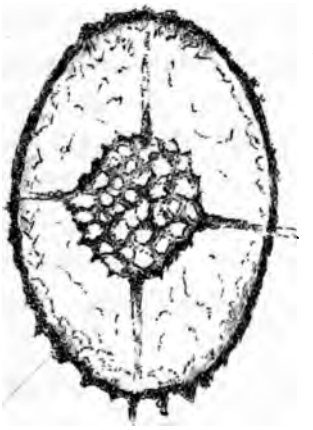

FIG. 2. One of the above casts magnified by 375.

Staurodruppa nucula, *Hinde*.

The outer test is shown in section; the meshwork of the inner test is beautifully preserved. When complete the specimen had four radial spines; only the bases and inner extensions of these have remained.

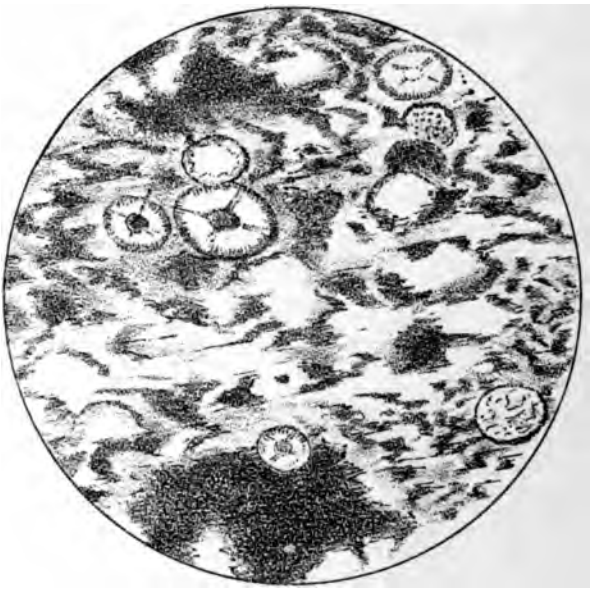

FIG. 1. From micro-photograph.

Radiolarian casts,

As shown in the field of a "student's microscope," with 1-inch lens, in a section of Chypons Chert, Mullion.

Chypons on its way to the sea at Pol-du Cove. There is a small bungalow at the bottom of the steep hill leading north from Chypons and adjoining the public road. Fifty yards north of this bungalow the road is cut through beds of the ordinary clay slates of the district, in which are interbedded several bands of radiolarian chert of variable thickness. A detached block is conspicuously visible in the western hedge. The beds in the eastern hedge are more or less hidden with soil and vegetation. In the northern bank of the garden immediately behind the bungalow, blocks are seen of the same rock associated with greenstone *in situ*. I have had this greenstone sliced for the microscope. Mr. Teall, F.R.S., was good enough to examine it for me, and describes it as follows:—

"A compact dark greenish rock, weathering brown at the surface and along cracks. It is composed of plagioclase augite and small grains of iron ore which have been more or less changed to leucoxene. Chlorite and probably also epidote occur as secondary products; the felspars are present as phenocrysts and also as constituents of the main mass of the rock in forms giving lath-shaped sections. The rock shows signs of crushing. It is very similar to some of the specimens from Mullion Island."

The interesting feature of this chert exposure consists in the fact that under the microscope some sections of this rock, although it is probably

of Lower Silurian age, show the delicate tracery and structure of the radiolaria in a better state of preservation, not only than any hitherto found in the more recent culm measures of East Cornwall, etc.,[1] but than any yet discovered in the United Kingdom. So well preserved are some of the forms that Dr. Hinde, F.R.S., has been able to describe eleven species, of which ten are new, while one has been previously recognised in the cherts of New South Wales. He has written a paper[2] on them which will probably appear in a forthcoming number of the *Quarterly Journal of the Geological Society.* This paper will be accompanied by sketches kindly drawn for me by Miss Gulielma Lister, supplemented by some of his own. The annexed plate gives a sketch of a micro-photograph of a section of this Chypons chert as shown in the field of a small "student's microscope" with a 1-inch lens. It will be seen that the structure is fairly well preserved in several of the radiolarian forms in this portion of the section. Mr. F. Chapman, A.L.S., also sketched for me one of the forms to which Dr. Hinde has given the name *Staurodruppa nucula.* It is magnified 375 times, as shown in the annexed plate (Fig. 2).

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[1] Vide *Q.J.G. Soc.*, vol. li. (1895), pp. 609-668.

[2] This paper was read Feb. 1st, and will appear in the *Q.J.G.S.* May 1st, 1899.

TAMAR.

About three miles south-east of Launceston, on the public road to Tavistock, and a quarter of a mile north of Greystone Bridge over the Tamar, there is a quarry of greenstone which has been used for road-metal. It is overlaid by shales interbedded with radiolarian cherts. The entrance of the quarry is cut through several feet of indurated slate and chert, the whole dipping apparently to the south-west. Sections of this chert show it to be densely crowded with casts of Radiolaria.

DEVONIAN FOSSILS.

Within the past few years I have found fossiliferous rock occurring in a few localities which, as far as I am aware, have not hitherto been recorded. The most interesting of these is Archer's Quarry.

ARCHER'S QUARRY.

About $4\frac{1}{2}$ miles south-west of Launceston, and 1200 yards west-north-west of Lewannick Church, there is a quarry of blue argillaceous slate, on the east side of the public road leading from Two Bridges over the river Inney to Bodmin. The rock dips south-east at a low angle, and has some fossiliferous beds. Dr. Hinde has kindly examined some of these organic remains, and writes as follows :—

"Fossils seem to have been fairly abundant in some of the beds. They are for the most part

poorly preserved as casts and impressions in rusty material. With the exception of a few crinoidal joints, the fossils appear to be all brachiopods. The following genera can be approximately determined: Orthis (two species); Chonetes; Streptorhynchus. I am unable to recognise the species, and cannot state the particular position in the Devonian series they indicate."

NOTE.—Since the foregoing paper was read, I have paid two more visits to Archer's Quarry, and procured some rather better fossils than before. Mr. J. H. Collins took the trouble of examining them, and writes as follows:—

"I have looked over your fossils from Archer's Quarry, and find pretty certainly *Chonetes Hardrensis* (Phill.), the little very finely striated shell, and *Spirifer disjuncta*, the large shell, also a smaller and more deeply ribbed Chonetes like *C. minuta*, with fragments of a Crinoid, and I think a Conularia. Archer's Quarry must be Upper Devonian if I have determined these species rightly."

Royal Geological Society of Cornwall.

THE EIGHTY-SIXTH

ANNUAL REPORT

ETC., ETC.

PENZANCE

1900.

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The Secretary requests the favour of his being informed of any inaccuracies in the foregoing lists.

THE

ANNIVERSARY ADDRESS OF THE PRESIDENT,

JOHN DAVIES ENYS, Esq., F.G.S.,

To the General Meeting, 7th November, 1899.

THE President, J. D. Enys, Esq., F.G.S., in his address gave a most interesting description of the general geological features of New Zealand, which was illustrated by maps of the country. From his long residence there Mr. Enys was able to lay before the members a large amount of information, and to relate many incidents connected with the subject, derived from his own experience, which enabled the members to appreciate fully the matter of the address. He then, on behalf of the Society, presented the William Bolitho gold medal for the year 1899 to Mr. Fortescue William Millett, F.R.M.S., in recognition of the valuable work, extending over a long period of years, which he has done, and especially of his investigations into the foraminifera of the Shell Beds at St. Erth.

Mr. Millett, in acknowledging the presentation of the medal, replied in the following words :—

It was in 1883 that I returned to Cornwall. For some years previously I had been engaged examining the *Challenger* dredgings with the view of finding specimens to assist Brady in the preparation of his report on the foraminifera of that expedition. This work was then drawing to a conclusion—in fact, it was published in the following year—and I was looking out for some other subject to engage my attention. Just then

Mr. Alfred Tylor was in Cornwall, and he asked me to show him some of the more salient geological features of the district. I took him to the hill above Marazion, from whence there is a good view of the sand-bar, which stretches from that town towards Penzance, and separates the sea from the marshy ground which extends towards Hayle. After looking for some time he remarked, "This is altogether different from what I expected to see; it puts me in mind of the Crag district. I wish you would look out here for crag deposits."

Some time after I happened to drop into a roadside public-house near St. Erth, where some quarrymen were discussing a question of geology. One of the men maintained that at one time there must have been a large river running through St. Erth, near the Vicarage. The others objected that the ground was too up-and-downy for any river to run there, but the first speaker had reason for his opinion. He triumphantly asked, "If there was no river there, how do you account for all the shells we are finding in the blue clay?" Shells in blue clay at St. Erth! Alfred Tylor's words at once recurred to me, and having by a few inquiries elicited that the blue clay was below the "head," and that the "head" had not been disturbed, I engaged one of the men to accompany me to the pit. There sure enough were the blue clay and the large shells. This of itself was wonderful enough, but when I pulled out my pocket magnifier and examined the microzoa I could not have been more astonished had I found a portion of the moon embedded in St. Erth.

Here as thick as flakes in a snowstorm were specimens of a genus of which hitherto only three or four examples were known to exist, besides many other things rare or unknown to science. Then I did what in those days everybody else did who had come across anything uncommon in nature, that is to say, I went to the late Mr. Thomas Cornish, of this town. He told me that he was already aware of the deposit, that he had sent some of the large shells to Searles Wood, and was then vainly endeavouring to convince him that they came from any deposit to be found in Cornwall. Mr. Cornish sent my notes on the microzoa to Searles Wood, and in a few days came his

reply. He had fully appreciated the importance of the discovery, and had made arrangements with the Secretary of the Palæontographical Society for the publication of a series of monographs on the various organisms to be found in the deposit.

He himself undertook the monograph of the mollusca, having secured the assistance of Robert Bell and J. Gwyn Jeffries. All the other organisms were turned over to me on the understanding that I was to work out all that I could myself, and to find competent specialists to undertake the remainder. First in importance were the foraminifera, and these I offered to Dr. H. B. Brady, but he replied that as I lived on the spot I was the proper person to undertake them, and he would always be ready to advise me in cases of difficulty. Thus fortified I undertook the monograph of the foraminifera.

Next in importance were the ostracoda, and these I offered to Dr. G. S. Brady, of Newcastle, who had devoted the greater portion of his life to the study of these organisms, fossil as well as recent. After examining the specimens I had sent him, he replied that they were so entirely different from any with which he was acquainted that he would not undertake them single-handed, so I succeeded in persuading David Robertson, the celebrated Scottish naturalist, to join him, and that monograph was at length provided for, and we all went to work with a considerable amount of enthusiasm.

But now comes the mournful portion of the history. First of all was taken Searles Wood, followed rapidly in succession by Gwyn Jeffries and Robert Bell. Thus were disposed of all those who had undertaken the monograph of the mollusca.

Next died my friend and adviser, Dr. H. B. Brady, and I was left to work out the monograph of the foraminifera without assistance.

Finally David Robertson was taken, and Dr. G. S. Brady being still unwilling to work out the ostracoda unaided, that monograph fell into abeyance.

Thus at this period, of all those who had undertaken the preparation of the monographs, the only survivors were Dr. G. S. Brady and myself.

But there were others more generally interested in the work whose loss we have to deplore. Amongst these may be named Mr. Alfred Tylor, Mr. Thomas Cornish, and Sir Warrington Smyth.

After the death of Searles Wood the study of the mollusca was taken up by Professor Etheridge and Alfred Bell, with the result that (thanks largely to the munificence of our President) the *Transactions* of the Society are enriched by a well-illustrated and valuable memoir.

And now, Mr. President and gentlemen of the Council, I have to offer you my sincere thanks for your consideration in conferring upon me this much-coveted distinction. Your kindness will ever remain in my memory, whilst the medal itself will henceforth be one of my most valued possessions.

REPORT OF THE COUNCIL

For the year ending 7th November, 1899.

THE most noteworthy fact concerning those matters which come within the scope of the interests of this Society, which has occurred since the Council presented their last report to the members, has been the great increase in the price of tin. The price of that metal—the particular glory of Cornwall—after remaining for many years so low that even the wisest management could hardly keep alive the best of our mines, rose in a few months, in the early part of this year, to a figure at which it is hardly too much to say that every mine in the county could be made to pay.

This Society is not concerned with the direct commercial aspect of this change, but the effect which it may have on the mining operations of the county is a matter directly pertinent to an institution which exists to maintain and encourage the study and knowledge of geology and mineralogy.

Up to the present time the increased price of their main product has not led to any great activity in the reopening of the abandoned mines or in the establishment of new enterprises, but there can be no doubt that if, as we have been led to believe, the present state of the market is to be of any long duration, we shall speedily see a great change in this direction, and the names of the mines which were once so famous will again become household words, telling their tale of industrious prosperity.

The history of Cornish mining through all the centuries of its existence has been one continued record of alternate periods of depression and prosperity. The change of the past year brings with it the hope that another period of depression has

passed away, and the turn of Fortune's wheel is bringing prosperity to our great industry once more.

Should these hopes prove well founded, we may also anticipate that the extension of the miners' work will add many valuable specimens to the splendid collection of minerals already to be found in this Museum.

In pursuance of the arrangement between them the joint meeting of the Cornish scientific societies was held this year under the management of this Society. Four interesting and valuable papers—viz., "St. Just Church," by Mr. T. C. Peter, for the Royal Institution of Cornwall; "Dangers of Modern Education," by Mr. A. Newland Deaken, for the Royal Cornwall Polytechnic; "Improved Methods of Mine Surveying," by Mr. W. Thomas, for the Mining Association; and "Deposits of the Red River Valley," by Mr. F. J. Stephens, F.G.S., for this Society—were read on that occasion. The Council feel a difficulty with regard to the printing in their *Transactions* of papers which are not in any way connected with geology, and they propose therefore to omit such papers from their published *Transactions*.

The work of the new Geological Survey continues, but in the absence of Mr. Wilkinson, who has been called to work elsewhere during a large portion of the year, the progress is not so rapid. Mr. J. B. Hill has been doing good and steady work.

Mr. J. H. Collins has continued his excellent service in arranging and cataloguing the fossil collection downstairs. The Council are pleased to record that as the result of his labours the working catalogue of the Cornish fossils has now reached 1,603, which means that so many specimens have been mounted on tablets in readiness for systematic study. Mr. Collins remarks in this connection that the names attached are not always consistent, as he has judged it best to retain the names originally given by Mr. Peach, and others, in those cases where the fossils have not since been the subject of systematic comparison. The record of the locality from which a fossil has been derived is in all cases of the first importance, and this Mr. Collins has in every case been most careful to preserve.

The Museum has attracted a large number of visitors during the year, and the Library increased, as will be seen by the report of the Librarian, by the usual number of valuable publications.

The Council have decided to recommend that the William Bolitho Gold Medal for this year should be awarded to Mr. Fortescue William Millet, F.R.M.S., of Marazion, in recognition of the patient and excellent work which has raised him to his present high and well-deserved position in the world of scientific men. The *Transactions* and the Library of this Society are enriched by many valuable papers by Mr. Millett, of which the greatest local interest attaches to those dealing with the foraminifera of the Pliocene clay beds at St. Erth.

The Council record with regret the death of Mr. W. Colenso, of Napier, New Zealand, an eminent native of Penzance, who was elected an honorary member of this Society at the last Annual Meeting.

LIBRARIAN'S REPORT

From November 1st, 1898, to October 31st, 1899.

THE following works have been added to the Library during the year :—

I. TRANSACTIONS, JOURNALS, AND REPORTS.

Presented by the respective Societies, Editors, and other Donors, or Purchased.

Adelaide. South Australian School of Mines and Industries and Technological Museum.
Tenth Annual Report, 1898. 8vo. Adelaide, 1899.

Boston. American Academy of Arts and Sciences.
Proceedings: Vol. xxxiv., Nos. 2–23, November, 1898, to June, 1899. Including Title-page, Index, and Contents of vol. xxxiv. Royal 8vo. Boston, 1898–1899.

Bristol. Naturalists' Society.
Proceedings: Vol. viii., part 3, New Series, 1897.
8vo. Bristol, 1899.

Brussels. Société Royale Malacologique de Belgique.
Procès Verbal: Vol. xxvii., pp. 73–100, September to December, 1898. 8vo. Bruxelles, 1899.
Bulletins Des Séances: pp. 1–96, Année 1899.
8vo. Bruxelles, 1899.

Buenos Aires. Museo Nacional.
Anales: Tomo vi. (Ser. 2a, t. iii.).
Imp. 8vo. Buenos Aires, 1899.
Comunicaciones: Tomo i., No. 2.
„ „ No. 3.
8vo. Buenos Aires, 1898–1899.

Cambridge. University Library.

Report of the Library Syndicate for the year ending December 31st, 1898. 4to. Cambridge, 1899.

Canada. Canadian Institute.

Proceedings: New Series, vol. i., part 6, No. 6, November, 1898. Including Title-page and Contents of vol. i.

Proceedings: New Series, vol. ii., part 1, No. 7, February, 1899. Royal 8vo. Toronto, 1898–1899.

——. Geological Survey of Canada.

Annual Report for the year 1896: New Series, vol. ix. With Maps. Royal 8vo, cloth. Ottawa, 1898.

——. Natural History Society of Montreal.

The Canadian Record of Science: Vol. vii., No. 8.
" " " Vol. viii, No. 1.
Including Title-page, Index, and Contents of vol. vii. 8vo. Montreal, 1898–1899.

——. Royal Society of Canada.

Proceedings and Transactions: Second Series, vol. iii., May, 1897. Imp. 8vo. Ottawa, 1897.

Chicago. Academy of Sciences.

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Bulletin: No. 2. The Pleistocene Features and Deposits of the Chicago Area. By Frank Leverett. Royal 8vo. Chicago, 1897.

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Proceedings (in separate pamphlets), viz.: The Self-cooling Condenser. By Thomas L. Wilkinson. Read May 6th, 1899.

The Sunset Trachyte, from near Sunset, Boulder County, Colorado. By Robert S. Breed. Read June 3rd, 1899. 8vo. Denver, 1899.

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Sitzungsberichte: Band xii., Heft i., 1898. 8vo. Dorpat, 1899.

Dublin. Royal Dublin Society.

Scientific Transactions: Vol. vi., Series 2, parts 14–16, April to August, 1898. Including Title-page, Index, and Contents of vol. vi.

Scientific Transactions: Vol. viii., Series 2, part 1. August, 1898. 4to. Dublin, 1898.

Scientific Proceedings: Vol. viii., New Series, part 6, November, 1898. Including Title-page, Index, and Contents of vol. viii. 8vo. Dublin, 1898.

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Transactions: Vol. vii., part 4. Including Title-page, Index, and Contents of vol. vii. 8vo. Edinburgh, 1899.

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India. Geological Survey of India.

General Report on the Work carried on for the period from 1st April, 1898, to 31st March, 1899. Royal 8vo. Calcutta, 1899.

Memoirs: Vol. xviii., part 1. Royal 8vo. Calcutta, 1899.

Palaeontologia-Indica: Series 15, vol. i., part 3. With plates 1–13. 4to. Calcutta, 1897.

A Manual of the Geology of India. Part 1. Including Index. Royal 8vo. Calcutta, 1898.

Indiana. Academy of Science.

Proceedings: 1897. Including Title-page, Index, and Contents of vol. Royal 8vo. Indianapolis, Ind., 1898.

Iowa. Geological Survey.

Annual Report: Vol. viii., 1897. With accompanying Papers. 4to. Des Moines, Iowa, 1898.

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Journal: Vol. xi., part 2.

Royal 8vo. Tōkyō, Japan, 1899.

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Transactions: Vol. v., part 1, July, 1898.

„ „ „ 2, October, 1898.

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Proceedings: Vol. viii., part 3, Session 40.

8vo. Liverpool, 1899.

——. Literary and Philosophical Society.

Proceedings: No. 52, Session 87, 1897–1898.

8vo, cloth. Liverpool, 1898.

London. Geologists' Association.

Proceedings: Vol. xv., part 10, November, 1898.

„ „ xvi. „ 1, February, 1899.

Including Title-page and Index of vol. xv., 1897–1898.

Proceedings: Vol. xvi., parts 2–4, May to August, 1899.

8vo. London, 1898–1899.

——. Geological Society of London.

Quarterly Journal: Vol. liv., part 4, No. 216, November, 1898. Including Title-page, Index, and Contents of vol. liv.

Quarterly Journal: Vol. lv., part 1, No. 217, February, 1899.

„ „ „ „ 2 „ 218, May, 1899.

„ „ „ „ 3 „ 219, August, 1899.

8vo. London, 1898–1899.

Catalogue of Geological Literature added to the Society's Library during the year 1898. 8vo. London, 1899.

List, November 1st, 1898. 8vo. London, 1898.

London. London, Edinburgh, and Dublin Philosophical Magazine. Series v., vol. xlvi., Nos. 282–283, November and December, 1898. Including Title-page, Index, and Contents of vol. xlvi.

Series v., vol. xlvii., Nos. 284–289, January to June, 1899. Including Title-page, Index, and Contents of vol. xlvii.

Series v., vol. xlviii., Nos. 290–293, July to October, 1899. 8vo. London, 1898–1899. *Purchased.*

——. Mines and Quarries.

General Report and Statistics for 1897. Parts 3–4.

Part 3. General Report and Statistics relating to the Output and Value of the Minerals raised in the United Kingdom, the Amount and Value of the Metals produced, and the Exports and Imports of Minerals.

Part 4. Colonial and Foreign Statistics: Statistics relating to Persons employed, Output, and Accidents at Mines and Quarries in the British Colonies and in Foreign Countries. Edited by C. Le Neve Foster, D.Sc., F.R.S. Folio. London, 1898–1899.

[Presented by C. Le Neve Foster, Esq.]

General Report and Statistics for 1898. Parts 1–3.

Part 1. Statistics of the Persons employed, Output and Accidents at Mines and Quarries in the United Kingdom, arranged according to the Inspection Districts.

Part 2. Labour: Relating to Persons employed and Accidents at Mines and Quarries in the United Kingdom, and to the Enforcement of the Mines and Quarries Acts.

Part 3. Output: Relating to the Output and Value of the Minerals raised in the United Kingdom, the Amount and Value of the Metals produced, and the Exports and Imports of Minerals. Edited by C. Le Neve Foster, D.Sc., F.R.S. Folio. London, 1899.

Presented by C. Le Neve Foster, Esq.]

Reports of C. Le Neve Foster, H.M. Inspector of Mines for the North Wales, etc., District (No. 9) under The Metalliferous Mines Regulation Acts, 1872 and 1875, and the Quarries Act, 1894, for the years 1897 and 1898.
Folio. London, 1898–1899.
[Presented by C. Le Neve Foster, Esq.]

London. Palaeontographical Society.
Vol. lii., for 1898. 4to. London, 1898. *Purchased.*

——. Quarry Publishing Company, Ltd.
Applied Geology. Part 2. By J. V. Elsden, B.Sc., (Lond.), F.G.S. 8vo. London, 1899.

——. Royal Society.
Proceedings: Vol. lxiv., Nos. 404–412, November, 1898, to April, 1899. Including Title-page, Index, and Contents of vol. lxiv.; vol. lxv., Nos. 413–419, May to October, 1899. 8vo. London, 1898–1899.

Manchester. Geological Society.
Transactions: Vol. xxvi., parts 1–8, Session 1898–1899. Including Title-page, Index, and Contents of vol. xxv.
8vo. Manchester, 1899.

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8vo. Manchester, 1899.

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Report of the Director of the Museum for the year 1898–1899. 8vo. Manchester, 1899.

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Boletin: Num. xi. 4to. México, 1898.

Montevideo. Museo Nacional de Montevideo.
Anales: Tomo iii., Fasgigulo x.
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4to. Montevideo, 1898–1899.

Milwaukee. Public Museum.

Sixteenth Annual Report: September 1st, 1897, to August 31st, 1898. 8vo. Milwaukee, Wisconsin, 1898.

Netherlands India. Jaarboek van het Mijnwezen in Nederlandsch Oost-Indië Uitgegeven op last van Zijne Excellentie den Minister Van Koloniën. 27th year, 1898. Vervolg Wetenschappelijk Technisch en Administratief Gedeelte.

28th year, 1899. Eerste Wetenschappelijk Geedelte. 8vo. Amsterdam, 1898–1899.

Newcastle-upon-Tyne. North of England Institute of Mining and Mechanical Engineers.

Transactions: Vol. xlvii., part 6, issued July, 1898.

" " " 7 " November, 1898.

[Including Title-page, Index, and Contents of vol. xlvii.]

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" " " 2 " December, 1898.

" " " 3 " April, 1899.

" " " 4 " May, 1899.

Royal 8vo. Newcastle-upon-Tyne, 1898–1899.

Annual Report of the Council for the year 1897–1898; List of Council, Officers, and Members for the year 1898–1899; Charter and By-laws, etc.

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Report of the Seventh Meeting held at Sydney, 1898. 8vo, cloth. Sydney, N.S.W., 1898.

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No. 5. Report on the Wyalong Goldfield. By J. A. Watt, M.A., B.Sc., Geological Surveyor.

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8vo. Sydney, N.S.W., 1899.

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Journal and Proceedings: Vol. xxxii., 1898. Including Title-page, Index, and Contents of vol.

8vo. Sydney, N.S.W., 1899.

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Vol. x., Nos. 1–12, October, 1898. Including Title-page and Contents of vol. x., 1897–1898.

Vol. xi., part 2, August, 1898.

„ „ 3, December, 1898.

Including Title-page, Index, and Contents of vol. xi.

Vol. xii., part 1, April, 1899.

Royal 8vo. New York, 1898–1899.

——. American Geographical Society.

Bulletin:

Vol. xxx., Nos. 4 and 5, 1898. Including Index of vol. xxx.

Vol. xxxi., Nos. 1–3, 1899.

8vo. New York, 1898–1899.

——. American Museum of Natural History.

Bulletin: Vol. x., 1898. Including Title-page, Index, and Contents of vol. x.

Royal 8vo. New York, 1898.

Annual Report of the President for the year 1898.

Royal 8vo. New York, 1899.

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Journal: Vol. xiv., parts 1 and 2, January to December, 1898.
8vo. Chapel Hill, N.C., 1898.

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Proceedings and Transactions: Vol. ix., Second Series, part 4, Session of 1897–1898. Including Title-page, Index, and Contents of vol. ix., 1894–1898.
8vo. Halifax, N.S., 1898.

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Proceedings: Parts 2–3, April to December, 1898.
„ „ 1, January to March, 1899.
Royal 8vo. Philadelphia, 1898–1899.

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Proceedings:
Vol. xxxvii., No. 158, December, 1898. Including Index to vol. xxxvii.
Vol. xxxviii., No. 159, January, 1899.
8vo. Philadelphia, 1898–1899.
Transactions: Vol. xix., part 3, New Series. Including Title-page, Index, and Contents of vol. xix.
4to. Philadelphia, 1898.

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Transactions: Vol. iii., part 4, April, 1898. Including Title-page, Index, and Contents of vol.
Imp. 8vo. Philadelphia, 1898.

Pisa. Societá Toscana di Scienza Naturali.
Processi Verbali: Vol. xi., pp. 58–158.
Royal 8vo. Pisa, 1898.
Memorie: Vol. xvi. Royal 8vo. Pisa, 1898

Sweden. Geological Institution (University of Upsala).
Bulletin: Vol. iv., part 1, No. 7, 1898.
Royal 8vo. Upsala, 1899.

Truro. Royal Institution of Cornwall.
Journal: Vol. xiii., part 4, 1898. Including Title-page, Index, and Contents of vol. xiii. 8vo. Truro, 1899.

United States. Department of the Interior. Geological Survey. Eighteenth Annual Report, 1896–1897. By Charles D. Walcott, Director. In Five parts. Part 1 containing Director's Report, including Triangulation and Spirit Levelling. Part 2.—Papers chiefly of a Theoretic Nature: "The Triassic Formation of Connecticut," by William M. Davies; "Geology of the Edwards Plateau and Rio Grande Plain adjacent to Austin and San Antonio, Texas, with reference to the occurrence of Underground Waters," by Robert T. Hill and T. Wayland Vaughan; "A Table of the North American Tertiary Horizons, correlated with one another and with those of Western Europe, with Annotations," by William H. Dall; "Glaciers of Mount Rainier," by Israel Cook Russell, with a Paper on "The Rocks of Mount Rainier," by George Otis Smith; "The Age of the Franklin White Limestone of Sussex County, New Jersey," by John Eliot Wolff and Alfred Hulse Brooks; "A Geological Sketch of San Clemente Island," by William Sidney Tangier Smith; "Geology of the Cape Cod District," by N. S. Shaler; "Recent Earth Movement in the Great Lakes Region," by Grove Karl Gilbert. Part 3.—Economic Geology: "Reconnaissance of the Goldfields of Southern Alaska, with some Notes on General Geology," by George F. Becker; "Geology of the Yukon Gold District, Alaska," by Josiah Edward Spurr, with an Introductory Chapter on the History and Condition of the District to 1897, by Harold Beach Goodrich; "Some Coalfields of Puget Sound," by Bailey Willis; "Geology and Mineral Resources of the Judith Mountains of Montana," by Walter Harvey Weed and Louis Valentine Pirsson; "The Mining Districts of the Idaho Basin and the Boise Ridge, Idaho," by Waldemar Lindgren, with a Report on the Fossil Plants of the Payette Formation, by Frank Hall Knowlton; "Preliminary Report on the Mining Industries of the Telluride Quadrangle, Colorado," by

Chester Wells Purington. Part 4.—Hydrography: "Report of Progress of Stream Measurements for the Calendar Year 1896," by Arthur Powell Davis; "The Water Resources of Indiana and Ohio," by Frank Leverett; "New Developments in Well Boring and Irrigation in Eastern South Dakota, 1896," by Nelson Horatio Darton; "Reservoirs for Irrigation," by James D. Schuyler. Part 5.—Mineral Resources of the United States, 1896—Metallic Products and Coal: "Iron Ores, Manganese Ores," by John Birkinbine; "Iron and Steel and Allied Industries in all Countries," by James M. Swank; "Witwatersrand Banket, with Notes on other Gold-bearing Pudding Stones," by George F. Becker; "Copper, Lead, Zinc," by Charles Kirchhoff; "Aluminium," by R. L. Packard; "Nickel and Cobalt," by Joseph Wharton; "Antimony, Coal," by Edward W. Parker. Mineral Resources of the United States, 1896—Non-metallic Products, except Coal: "Coke, Asphaltum, Soapstone, Abrasive Materials, Sulphur, and Pyrites, Gypsum, Fluorspar and Cryolite, Mica, Asbestos, Mineral Paints, and Barytes," by Edward W. Parker; "Petroleum, Natural Gas," by F. H. Oliphant; "Stone," by William C. Day; "Statistics of the Clay-working Industries in the United States in 1896," by Jefferson Middleton; "The Clay-working Industry in 1896," "Felspar and Quartz," by Heinrich Ries; "Mineral Waters," by Albert C. Peale.

Nineteenth Annual Report, 1897–1898. By Charles D. Walcott, Director. Parts 1, 4, and 6. Part 1 containing Director's Report, including Triangulation and Spirit Levelling. Part 4.—Hydrography: "Report of Progress of Stream Measurements for the Calendar Year 1897," including Papers by Dwight Porter, J. B. Lippincott, and other Hydrographers, by F. H. Newell; "The Rock Waters of Ohio," by Edward Orton; "Preliminary Report on the Geology and Water Resources of Nebraska, West of the One Hundred and Third Meridian," by N. H.

Darton. Part 6.—Mineral Resources of the United States, 1897—Metallic Products, Coal and Coke: "Iron Ores and Manganese," by John Birkinbine; "The American and Foreign Iron Trade in 1897 and immediately Preceding Years," by James M. Swank; "Copper, Lead, and Zinc," by Charles Kirchhoff; "Antimony, Coal, and Coke," by Edward W. Parker; "Platinum," by David T. Day. Mineral Resources of the United States, 1897—Non-metallic Products, except Coal and Coke: "Petroleum and Natural Gas," by F. H. Oliphant; "Asphaltum, Soapstone, Abrasive Materials, Sulphur and Pyrites, Gypsum, Salt, Fluorspar and Mica, Asbestos and Graphite, and Mineral Paints," by Edward W. Parker; "Stone," by William C. Day; "Clay Statistics," by Jefferson Middleton; "The Kaolins and Fire Clays of Europe," by Heinrich Ries; "Precious Stones," by George F. Kunz; "Mineral Waters," by A. C. Peale; "Memorandum on the Mineral Resources of the Philippine Islands," by George F. Becker.

4to, cloth. Washington, 1898–1899.

United States. Monographs:

Vol. xxix. Geology of Old Hampshire County, Massachusetts. By Benjamin Kendall Emerson.

Vol. xxx. Fossil Medusæ. By Charles Doolittle Walcott.

Vol. xxxi. Geology of the Aspen Mining District, Colorado, with Atlas. By Josiah Edward Spurr.

Vol. xxxv. The later Extinct Floras of North America. By John Strong Newberry.

4to, cloth. Washington, 1898.

——. Bulletins:

No. 88. The Cretaceous Foraminifera of New Jersey. By Rufus Mather Bagg, jun.

No. 89. Some Lava Flows of the Western Slope of the Sierra Nevada, California. By F. Leslie Ransome.

No. 149. Bibliography and Index of North American Geology, Palæontology, Petrology, and Mineralogy for the year 1896. By Fred Boughton Weeks.

8vo. Washington, 1897–1898.

United States. Atlas:

On the Geology of the Aspen District, Colorado. By Josiah Edward Spurr.

To accompany Monograph xxxi.

Elephant Folio. Washington, 1899.

Victoria. Department of Mines.

Annual Report of the Secretary for Mines and Water Supply. Including Reports of the working of Part 3 of the Mines Acts, 1890 and 1897; Water Supply, etc. etc. etc., during the year 1898. Folio. Melbourne, 1899.

——. Geological Survey of Victoria.

Progress Report (No. x.).

„ „ (No. xi.). Folio. Melbourne, 1899.

Monthly Progress Report (New Series), No. 1, April, 1899. Royal 8vo. Melbourne, 1899.

Vienna. K.K. Geologischen Reichsanstalt.

Verhandlungen: Nos. 13–18, 1898. Including Title-page, Index, and Contents of vol. for 1898.

Verhandlungen: Nos. 1–8, 1899.

Royal 8vo. Wein, 1898–1899.

Washington. Smithsonian Institution.

Annual Report of the U.S. National Museum for the year ending June 30th, 1896.

Royal 8vo, cloth. Washington, 1898.

Earth-crust Movements and their Causes. By Joseph Le Conte.

Crater Lake, Oregon. By J. S. Diller.

Rising of the Land around Hudson Bay. By Robert Bell.

The Age of the Earth as an Abode Fitted for Life. By Lord Kelvin. Royal 8vo. Washington, 1898.

Wisconsin. Geological and Natural History Survey.

Bulletin: No. 1, Economic Series, No. 1.

„ „ 2, Scientific Series, No. 1.

Royal 8vo. Madison, Wis., 1898.

Wisconsin. Academy of Sciences, Arts, and Letters.
Transactions: Vol. xi., 1896–1897.
,, ,, xii., part 1, 1898.
Royal 8vo. Madison, Wis., 1898.

Yorkshire. Geological and Polytechnic Society.
Proceedings: New Series, vol. xiii., part 9.
8vo. Leeds, 1899.

II. GEOLOGICAL AND MISCELLANEOUS PUBLICATIONS.

Presented by the Authors or other Donors.

Hinde, G. J. On the Radiolaria in the Devonian Rocks of New South Wales. By George Jennings Hinde, PH.D., F.R.S., F.G.S. 8vo. London, 1899.
[Presented by the Author.]

Holland, T. H. A Manual of the Geology of India.
Part 1. Corundum. By T. H. Holland, A.R.C.S., F.G.S.
Royal 8vo. Calcutta, 1898.
[Presented by the Author.]

Millett, F. W. Report on the Recent Foraminifera of the Malay Archipelago. Collected by Mr. A. Durrand, F.R.M.S.
Parts 1–5. By Fortescue William Millett, F.R.M.S.
8vo. London, 1898–1899.
[Presented by the Author.]

Rutlidge, C. S. Guide to Queensland. By Charles Schaefer Rutlidge, F.RG.S., F.R.C.I. 8vo. London, 1898.
[Presented by the Hon. Sir Horace Tozer, K.C M.G., Agent-General for Queensland.]

CURATOR'S REPORT, 1899.

DONATIONS TO MUSEUM.

NAME AND LOCALITY.	DONOR.
Gold in quartz, Orgum Mine, Mysore	W. Eddy.
Silver ore, Emma Mine, Salt Lake City, U.S.A.	W. Eddy.
Pitchblende, St. Stephens	B. Kitto.
Autunite „	B. Kitto.
Autunite with torberite, St. Stephens	B. Kitto.
Torberite, St. Stephens	B. Kitto.
Landscape marble	F. W. Millett.
Lime from Levant	Purchased.
Red granite from Pendeen	Miss Borlase.
Crystals of natrolite from the serpentine of Chynhalls, Coverack	Harford J. Lowe.
Petraia celtica, very perfect cup coral from Polruan	John Menear.
Fragment of spine of *Climatius*, Ag., from Watergate Bay	Rupert Vallentin.
Mr. Clark's original drawings of *Nereitopsis(?)*	Upfield Green.
Igneous rock from Gulland Island. Nos. 679, 680, 681	Howard Fox.
Three photographs of Gulland Island	„
Photograph of Prof. Barrois, of Lille	„
Petraia, etc., fossils from CANT HILL, St. Minver	„
Petraia from DENNIS COVE, Padstow	„
Fossils from TREVONE—	
Favosites (?)	„

NAME AND LOCALITY.	DONOR.
From NEWTRAIN BAY—	
Two species of *Favosite* corals . .	Howard Fox.
Arms of a crinoid somewhat like those of *Scaphiocrinus*. See Whidborne, *Pal. Soc.*, vol. iii., part 3, 1898, pp. 228–232, Pls. xxxi., xxxiii.–xxxviii. . . .	,,
From MOTHER IVEY'S BAY—	
Centronella	,,
Tentaculites, etc.	
Crinoidal stems	
Orthoceras (?)	
Hyolithes	
From CONSTANTINE BAY—	
Slender *Orthoceras* . . .	,,
Gasteropod (?)	
From PORTHCOTHAN—	
Trilobite tail	,,
,, ,, ...	
Corals	
Pleurodictyum	
Goniatite	
Petraia from the Arched Rock, south end of cove	
Petraia from Wills Rock, north end of cove	
Sundry *Petraias*	
A *Trilobite*, minus the head, determined by Dr. H. Woodward to be a species of *Phacops*	,,
Two pygidia of *trilobites* . . .	,,
From PORTH MEAR—	
Pleurodictyum	,,
Orthoceras	
Petraia	

NAME AND LOCALITY.	DONOR
From LOWER BUTTER COVE—	
Conularia	Howard Fox.
Petraia, in good preservation . .	
Pleurodictyum	
Fragments of *Pteroconus mirus*, nov. nom., Hinde	
From BEDRUTHAN STEPS—	
Ganoid fish, portion of (A. Smith Woodward, F.G.S.)	,,
Fragment of fish plate (?) . . .	
Crinoidal stems of *Rhodocrinus* or *Melocrinus*, etc.	
Basal plate of the cup of crinoid similar to *Sphærocrinus*, a Middle Devonian form (F. A. Bather)	
Michelinia	
Pleurodictyum	
Aulopora	
Zaphrentoid cup coral, *Lophophyllum (?) Z.calceoloides*, Champernowne. Cf. *Q.J.G.S.*, 1884, p. 497, Pl. xxi. figs. 1*a*, 1*b*, and fig. 6	
Nondescript organism . . .	
Gasteropod *Murchisonia (?)* . .	
Coral species (?)	
Portion of fish plate belonging to genus *Scaphaspis*. Determined by A. Smith Woodward, F.G.S., Brit. Mus. . .	
Monticuliporoid, or Polyzoön . .	
Anal tube of *Dicyclic inadunate crinoid* (Bather)	
Joint of stem of large crinoid . .	
Plate of crinoid (?) with spine attached (Jækel, *Acanthocrinus Pal.*, 95, vol. vii.)	
Sundry crinoidal stems . . .	

NAME AND LOCALITY.	DONOR.
Pteroconus mirus, nov. nom., Hinde = *Nereitopsis*, Green, several specimens, one of which is 72 mm. long by 6 mm. broad	Howard Fox.
Casts of *Pteroconus mirus*, figured in the *Geol. Mag.*, April, 1900, pl. vii. . .	"
From WATERGATE BAY—	
Pteraspis plates	"
Fragments of fish spines allied to the genus *Climatius*	
Crinoid stem	
From GUNWALLOE—	
Crinoidal stems	"
Crushed *trilobite (?)* . . .	
Ptilodictyum (?)	
"	
"	
Nematophycus (?), Carruthers. *Q.J.G.S.*, vol. xxxvii., 1881, p. 490. . .	"

TREASURER'S STATEMENT, 1898–99.

Dr. *The Treasurer in Account with the Royal Geological Society of Cornwall.* **Cr.**

November 7th, 1899—	£	s.	d.
To Ordinary Subscriptions and Arrears	50	8	0
,, Donation per H.R.H. The Prince of Wales ...	20	0	0
,, One Year's Dividend on £1500 Midland Railway 3% Debenture Stock, less tax, 30/-	43	10	0
,, Sale of Transactions	0	12	6
,, Balance	48	9	4
	£162	19	10

November 8th, 1898—	£	s.	d.
By Balance	37	14	7
November 7th, 1899—			
By Rates and Taxes	0	4	0
,, Housekeeper's Salary	20	0	0
,, Curator's Salary	50	0	0
,, Fire Insurance Premium	2	12	9
,, Books, Binding, &c.	29	10	9
,, Coals, Gas, Cleaning, &c.	8	8	1
,, Repairs to Buildings, &c.	0	18	0
,, Palæontographical Society	1	1	0
,, Tablets and Labels per J. H. Collins & Sons ...	5	1	0
,, Specimen Lime and Quartz from Levant Mine ...	0	10	0
,, Sundry Expenses per Secretary—Stationery, Postages, Advertising, &c.	6	19	8
	£162	19	10
,, Balance due to Treasurer	48	9	4

PENZANCE.

T. ROBINS BOLITHO, *Treasurer.*

Dr. *The Treasurer in Account with the Royal Geological Society of Cornwall.* **Cr.**

DEPOSIT—OLD ACCOUNT.

			£	s.	d.
1896—November 10th.	To Balance	...	41	13	7
1897— ,, 9th.	,, Interest to Date ...	...	1	18	0
		£43	11	7	
1898— ,, 8th.	,, ,, ...	...	1	1	6
		£44	13	1	
1899— ,, 7th.	,, ,, ...	...	1	2	0
		£45	15	1	

LATE W. BOLITHO, JUN., LEGACY ACCOUNT.

			£	s.	d.
1898—November 8th.	To Balance	...	511	7	6
1899—	,, Interest to 15th April ...		13	12	6
		£525	0	0	
1899— ,, 7th.	,, Balance	£512	10	0	

			£	s.	d.
1899—November 3rd.	By Gerrard & Co. for Gold Medal		12	10	0
,, ,, 7th.	,, Balance		512	10	0
		£525	0	0	

PENZANCE.

T. ROBINS BOLITHO, *Treasurer.*

LIST OF

PAPERS READ AT THE ANNUAL JOINT MEETING

OF THE CORNISH SCIENTIFIC SOCIETIES,

September, 1899.

Some Dangers of Modern Education. By A. Newland Deakin.

Improved Methods of Mine Surveying. By Wm. Thomas.

St. Just Church. By Thurstan C. Peter.

Alluvial Deposits of the Red River Valley.
By F. J. Stephens, F.G.S.

LIST OF

PAPERS READ AT THE ANNUAL MEETING,

November 7th, 1899.

Acknowledgment of the William Bolitho Medal.
By F. W. Millett, F.R.M.S.

A Natrolite from Coverack. By Harford J. Lowe.

Some Fossil Cephalopoda. By C. Crick, F.G.S.

Geological Notes. By Howard Fox, F.G.S.

NOTES ON EXPEDITING MINE SURVEY WORK.

By William Thomas,
Assoc. M. Inst. C.E.

(Read at the Annual Joint Meeting, September, 1899.)

It is obviously an advantage to expedite any section of surveying work, provided that the adoption of the faster method does not lessen the accuracy of the survey. It may be quite correct to maintain that all surveys should be accurate, yet one is perfectly justified in qualifying such a statement by adding, "Yes, as accurate as circumstances may demand, or as circumstances may permit." A survey, made with the object of ascertaining agricultural values of land, say, for the purpose of selling crops, or even the land itself, does not necessarily demand the accuracy which is essential in laying down the boundaries of a metal mine or in communicating an important shaft and a rise against it. The two surveys would, in all probability, be performed by two different methods, each of them being legitimately applicable to the case. The surveyor naturally suits his method to the character and object of the survey and to the consequences attached to it, having also due regard

to the scale of fees paid for his work. Surveys may be performed by chain and off-sets alone, with results that are quite satisfactory for some purposes. On the other hand, some surveys can only be satisfactorily performed by the aid of high-class instruments, requiring careful and skilled handling. Consequently, it is not to be expected that the same means of expediting work can be applied to all surveys. The object of the writer is to briefly note some means of expediting mine surveys, and in so doing to invite attention to certain instruments adapted for this work. These instruments are on the table.

In making the survey of a mine it is important, at the outset, to get the surface boundaries done. In the majority of cases a triangulation survey of the property to this end is not only expeditious, but it ensures accuracy and affords abundant means of definite checking. The filling in of details upon the triangulation skeleton thus produced may occupy much time, and it is in this part of the work that the surveyor may well consider the various means of hastening his work. In traversing by the aid of the theodolite in the ordinary manner the time is mainly occupied in making the chain and off-set measurements. If the plane table is used instead of the theodolite, the taking of angular measurements is somewhat expedited, especially if the form of plane table selected is the "Rapid Traverser," introduced by Mr. J. Henderson, M.Inst.C.E. This is, for general mining work, the best form of plane

table in use. It is rapid, and is easy to use, and it saves time in the office. But with the plane table it is, of course, necessary to measure the lines and off-sets in precisely the same way as when the angles are taken with the theodolite.

Where a rough or hilly surface has to be surveyed, or where minute details are not required, the tacheometer is an excellent instrument to use. It gives all the accuracy of the theodolite in angular measurements—indeed, it *is* a theodolite of special construction—and it does away with the use of chain and band. There is little difficulty in obtaining results which compare favourably with the measurements of the chain in this way up to distances of 500 or 600 feet, using the 4″, 5″, or 6″ tacheometer of ordinary construction and an ordinary Sopwith levelling staff.

Photographic surveying makes a still greater advance, for it not only does away with line measurement, but practically throws off the note-book as well, for, when using such an instrument as the photo-theodolite, invented by Mr. J. Bridges-Lee, a note-book is scarcely required. The earliest photographic surveying work appears to have been done about 1850, and from that date up to about 1890 experiments were made with some degree of success in Germany, Austria, and Italy. But it is in Canada, especially since 1892, that this method of rapid surveying has been most extensively applied, under the direction of Mr. E. Deville, the Surveyor-General of Dominion Lands. In 1893

and 1894 an International Boundary Commission was appointed to examine into the boundary between Alaska and N.W. Canada. The Canadian Commissioner, Mr. W. F. King, conducted his portion of the survey by photography, and covered 14,000 square miles in the two years. There is undoubtedly a field for the use of the photo-theodolite in conducting preliminary surveys and filling in triangulation surveys of new mining districts. By making use of triangulation stations for the chief points of photographic reference, a very rapid and sufficiently accurate set of intersections can be secured. This should be much more rapid than either the plane table or tacheometer, and applicable to work which neither of those instruments would properly treat.

It is sometimes desirable to make a survey of a mine from the mining expert's point of view rather than from that of the surveyor. This has invariably to be rapidly done, and, since the plans obtained are in all such cases approximate only, a portable instrument, which is quickly and easily adjusted, is to be desired for this kind of work. The very neat and compact little prismatic compass constructed by Mr. G. A. Troye, and fitted with horizontal circle and a detachable protractor, all mounted on an aluminium tripod, is perhaps one of the most useful instruments for the mining expert's use. The whole goes into the pocket, and is very light.

Time does not permit, in a fifteen-minute paper, anything beyond a brief description of the instru-

ments mentioned, and the writer has thought it best rather to enumerate some of the good features of each of the instruments than to enter into a discussion of the advantages and disadvantages attending their use. As intimated previously, the same means of expediting cannot be applied to all surveys. It is quite safe, however, to assert that each of the instruments mentioned is exceedingly useful—in its place—for expediting mine survey work.

ALLUVIAL DEPOSITS IN THE LOWER PORTION OF THE RED RIVER VALLEY, NEAR CAMBORNE.

(AS PROVED BY BORING OPERATIONS DURING 1898-9.)

By F. J. STEPHENS, F.G.S.

(Read at the Annual Joint Meeting, September, 1899.)

INTRODUCTION—DESCRIPTION OF VALLEY.

THE Red River is a fairly large stream which, rising on the high ground of Bolennowe Moors, three miles south-east of Camborne, flows down across the mining district, in the valley between Dolcoath and Cook's Kitchen and below Tucking-mill.

Thence, joined by other streams, it flows westward through a deep valley almost at right angles to its higher course, until it falls into St. Ives Bay at Gwithian.

This lower portion of the Red River Valley is much flatter than the higher portion, and in consequence is more or less covered with alluvial deposits.

Rising in granite highlands, the river enters the "killas," or slate series, about Condurrow.

The mines find this stream very useful for their

ore dressing operations, and below the mines themselves a large number of works have been erected for the purpose of treating the slimes and sands washed down by the Red River. The amount of tin obtained from this source is considerable.

It must be distinctly understood that, whereas these modern tin stream-works deal with material which is the waste of modern mining operations, the ancient tin-streamers dealt with alluvial tin gravel—waste and débris torn from the high hills in prehistoric days, and washed many miles down the valleys.

A mile and a half above the sea the main valley is joined by the Roseworthy Valley, which is watered by a stream of some size.

This rises in Crowan parish, and flows down past Bareppa, Lower Penponds, and Roseworthy, until it joins the Red River at South Nancemellin.

This valley in former times was very rich in alluvial tin gravel. Tradition has it that the ground covered by an ox lying down would produce sufficient tin to pay the value of the ox.

THEORIES AS TO ALLUVIAL TIN GROUND IN THE RED RIVER VALLEY.

Below the junction of these two valleys the alluvial appeared to have never been touched. Above this point the early tin-streamers had apparently done a good deal of work.

It was considered probable that this lower reach,

nearly one and a half miles in length, might contain a quantity of alluvial tin gravel.

The chief argument in favour of this theory was the idea that the sea in former times (within historic period in fact) had stretched as a tidal creek at least as far up as the junction of the valleys.

It was supposed that the old workers had not been able to touch the theoretical tin gravel owing to the tidal waters.

In the autumn of last year (1898) the writer prepared a paper in which these theories were discussed in detail.

Tradition, maps, and other matter were called into requisition, and all tended to show that at all events the lower part of the Red River Valley had never been worked.

In December this paper was read before members of the Mining Institute of Cornwall, and will appear in the *Transactions* of that Society in due course.

A private syndicate for exploring this part of the valley had been formed previously, and the writer was in charge of the operations from their start to the finish.

The superficial extent of the valley as included within the licences amounted to several acres, and to explore this ground a method of boring at regular intervals was resorted to.

PROSPECTING OPERATIONS AND MACHINERY USED.

About 200 holes altogether were put down to the bed rock. The distance between each hole was 150 feet, as a rule. Each line of holes was carried out in diagonal rows across the valley.

No holes were allowed to be bored within 30 feet of the artificial banks of the Red River on either side. These banks were some 15 to 18 feet apart, outside measurements.

This stipulation was a very wise one, for the Red River in years past has been often choked by quantities of sand, and has flooded the valley. It is now kept within its limits by high artificial banks, made of double rows of faggots, backed with earth. The width of the valley varied from 800 feet near Nancemellin to 40 feet below Reskajeage marsh.

The bore-holes were 5 inches in diameter, and to put them down a small set of boring tools made by Richards and Co., of Southwark, was used. This consisted of a light steel tripod, barely over 1 cwt. in weight, and with hollow legs 14 feet in length. It was capable of bearing a weight of 30 cwt.

Ten-feet lengths of $1\frac{1}{4}$-in. square steel rods were used with chisels, augers, and shells for the actual cutting tools. Short matching pieces, 3 feet in length, were very useful. The pod or hollow part of the largest auger was nearly 3 feet in length.

In operation the auger was screwed down by hand through the peat and gravel until it choked.

It was then withdrawn, and the contents carefully noted and examined. A fresh cut was then taken, and repeated until the bed rock was reached. As a rule, each hole was sunk in material firm enough to keep the sides intact, but occasionally it became necessary to use a lining tube, which was driven down by heavy blows from an iron monkey weighing 2 cwt. This instrument was conical-shaped, with a hoisting ring at the small end and a long rod or tail at the broad end to keep it from slipping off the pipe.

This was hoisted by a threefold pair of blocks, and then allowed to fall upon the sinking tube. These were 10 feet in length, with flush-screwed interior and exterior threads, protected at either end by a driving and sinking shoe of hard steel.

The weight of each 10 feet of rods was about ½ cwt., and the weight lifted from each hole at its completion was often 2 cwt. If, as often happened, the peat and clay were plastic, and consequently falling in around the auger, the weight was as much as three men could break out with the threefold blocks.

Lining tubes were withdrawn by a pair of Weston pulley blocks.

From four to six holes were put down each day, a good deal, of course, depending upon the compactness of the alluvial and the weather. On an average the holes were about 20 feet in depth.

The material was carefully examined at each lift, and washed. Often three or four samples were

vanned from each bore-hole. One was invariably taken from the bottom gravel.

The operations were unusually free from small accidents to the tools, and the only narrow escape was caused by the tripod blowing over in a heavy gale of wind.

RESULTS AND DESCRIPTION OF THE SECTIONS.

The result of the borings was to prove undoubtedly that the alluvial had never been disturbed by human agency. Poor tin gravel was met with constantly, but no rich pockets or patches of payable gravel rewarded the syndicate.

No less than three distinct layers of peat were met with in the lower part of the valley, and sometimes four. In the higher part, for about a mile below South Nancemellin, two layers occurred, the lower one being some 6 or 7 feet beneath the surface.

Two or three layers of stiff clay or consolidated mud were passed through in the lower part of the valley. This thinned out towards Nancemellin on the sides, but in the centre part was never entirely absent. This material contained no shells, but was evidently estuarine mud, yellowish blue to light grey in colour.

One peculiar feature of the operations was the regular depth of the bore-holes. A broad tract in the centre of the valley varied scarcely 2 feet in depth. The holes near the sides were a few feet

less, but the sum of the borings went to prove the former existence of a shallow tidal estuary with no deep channel or old river bed in the centre as was expected.

No specimens of interest were taken from the bore-holes. Pieces of soft reddish wood—probably alder—were cut through and brought up, and in one instance a hard trunk of a tree prevented sinking to the bed rock. This was probably bog oak, as fragments of woody fibre came up in the auger.

At the Gwithian end of the valley vast quantities of drifted sea-sand or towans cover the alluvial, and sinking through this material proved a matter of great difficulty. In fact, only three bore-holes could be got down in the beach section, and of these two occupied three full days. The depth of drifted sand varied from 3 to 10 feet, and continuous tubing had to be resorted to.

TIN GRAVEL.

The gravel occurred in different layers and of different composition. That below the surface contained fragments of copper ore, mostly grey sulphide. This may very probably have been the débris from the large copper mines of the Camborne District, worked towards the end of last and in the early part of this century. The proportion of copper ore was much greater near Nancemellin. In the lower part of the valley the bottom gravel

consisted largely of fragments of slaty material. Higher up rounded pebbles of granite elvan, tin, capel, and other material from the high ground became abundant.

Few holes failed to pass through gravel. It appeared to be spread all over the bed rock. It varied, however, greatly in thickness, being usually about 1 foot in depth, but sometimes as much as 8 feet. The top gravel seemed to be spread universally. Its presence may be attributed to the fact that modern tin-streaming did not begin until about 1860. Before this period the copper mines discharged vast quantities of débris down the Red River, which then wandered anywhere about the valley.

The peat was sometimes reddish in colour, usually being, however, from dark brown to black.

MINERALS.

The object of the bore-holes was, of course, to discover a sufficiently payable quantity of tin. A little tin was invariably met with, from 1 to 1¼ lbs. per ton being a fair average. In two cases the samples averaged over 30 lbs. per ton, and one sample ran as high as 42 lbs. per ton. Sinking in the immediate vicinity failed, however, to discover a continuation of this high produce.

The quantity of copper contained in the upper part of the gravel was very considerable. Two or three samples were carefully assayed, and as much

as 2 per cent. of copper was extracted. This at the present high price of the metal is worth attention. Probably the average value of the gravel may be taken at as about 1 per cent. of copper.

Several interesting facts present themselves. The top thickness of clay appears to lie almost evenly along the valley bottom.

It is met with immediately underlying the peat, or at a depth of about 2 feet, in Reskajeage Marsh, which is in the lower part of the valley. Higher up, where the surface is some 5 feet above the datum line, we find the clay at a depth of 7 or 8 feet.

We find the bottom gravel almost universally persistent. It is very granitic near the top of the valley, and contains certainly less than 10 per cent. of slate fragments. In Reskajeage Marsh the percentage of slate fragments is as much as 70 per cent. Many of these lower fragments are angular and subangular, and local in origin.

The upper or top gravel is evidently recent detritus. It may safely be assumed that this material, consisting largely of copper ore detritus, was washed down wholesale by the old river before it was kept within its present bounds. The copper-bearing lodes of the Camborne District were in full swing during portions of last century and from early in this century until some thirty years ago.

This gravel spreads over the valley lying upon the clay in a wedge-shaped deposit, gradually fining

off from about 8 feet thick at Nancemellin to 12 inches just above the farmhouse at Reskajeage.

The clay is also extremely persistent. It is the chief feature of the lower bore-holes, and is not entirely absent even in the highest up the valley.

A lower and thin deposit of clay is also met with nearer the bed rock. No shells were found in the clay, but the deposits are evidently estuarine, and mark at least two periods of tidal waters in what was then a creek similar to the Penryn River.

In the same way the peat beds are numerous and persistent. There are three in a bore-hole 40 feet east of Gwithian Bridge—three distinct layers. Some of the lower peat deposits gave out a strong and distinct odour of SH_2, and on one occasion at least I detected carburetted hydrogen gas.

The lowest bed of peat rested on the bottom gravel, and was usually of a deep reddish colour. This did not, however, extend far up the valley. In all other cases the older peat was found lying upon the clay.

The peat beds now on the surface of the marsh lie on gravel at the upper end of the valley and on clay nearer the sea.

The drifted sand near the seashore extends downwards to a great thickness. Under it we find little but gravel—no peat, no clay. It would seem that the former tidal creek ended in a deep little bay, which has now been entirely choked and

lost, and the sea driven back. This may be attributed to the combined influences of drifting sand from the dunes, and the accumulation of surface detritus from the older mines.

GENERAL CONCLUSIONS.

In the far-away days when tin gravel was deposited in our valleys they were as a rule much deeper, or the land was higher—much the same thing.

In the case of the Red River we find clay and peat lying above the gravel, showing that estuarine and marshy conditions prevailed and alternated for a long period of years. The beds of clay and peat are thin, and uninterrupted deposition could not have been of long duration.

The thick bed of clay, which so persistently continues for nearly one and a half miles up the valley, marks a time when a broad tidal creek ebbed and flowed probably a good way up both the Roseworthy and Red River valleys. In those days the district must have resembled the lower reaches of the Fal.

On the north side of the Reskajeage Marsh the peat is deep, and forms a sink in the clay. This was doubtless the old bed of the creek, which has gradually been filled with peaty material. (The yellow iris grows plentifully in this marsh.)

A hollow in the clay itself has been filled with sand, and may mark either an older or a more

recent river or creek bed. It doubtless meandered about the valley, as is the wont of creeks.

Very little of geological interest has been added to our knowledge as the result of these operations. The bore-holes have proved undoubtedly the fact that the Red River Valley was formerly an arm of the sea. This we may have surmised before. Yet, as the record of actual operations, which in themselves were the result of theory and geological reasoning, the results are, the writer ventures to think, worthy of notice.

NATROLITE FROM THE COVERACK DISTRICT.

By Harford J. Lowe, Esq.

Among the innumerable veins that traverse the rocks in the Lizard District I noticed one in the vertical face of the serpentine at Chynhalls Point that contained a light-coloured mineral of somewhat peculiar appearance. This vein runs in a nearly horizontal direction somewhat above high-water mark. It is in places about an inch and a half across, in others a mere joint. The mineral referred to assumes a radiate form from many centres, so that the needle-like crystals spread out in fan-shapes from the various points of origin when the mineral is seen in section. The centres of radiation appear to be irregularly disposed within the fissure, although the majority lie on the outside of the mass as though originated upon the walls of the fissure. From these points of origin the crystals radiate in every possible direction, so that irregular spheroids of rays are from centres lying between the walls of the fissure, while hemispheroids of less pure crystals result from centres lying on the walls of the fissure. In either case the crystal rays are terminated

by contact with a fellow-crystal growing from another centre.

Through the kind interest of Mr. J. H. Collins, F.G.S., this crystal has been identified by Mr. G. T. Prior, M.A., F.G.S., of the British Museum, as the hydrated silicate of soda and alumina, known as *Natrolite*. This is one of the rarest of British minerals, and in Cornwall it has heretofore only been certainly found at St. Just, in the cliffs between Botallack and Wheal Cock, and at Wheal Carne, at which places it is associated with *Prehnite* and *Stilbite*. It has been somewhat doubtfully reported as occurring at Stenna Gwynn, in St. Stephens, but this occurrence needs confirmation.

NOTE ON SOME FOSSIL CEPHALOPODA FROM CORNWALL.

By G. C. Crick, F.G.S.,
Of the British Museum (Natural History).

Communicated by J. H. Collins, F.G.S.

The specimens referred to in the present note belong to the Penzance Museum, and have been brought under my notice by Mr. J. H. Collins.

CYRTOCERAS SP. (Fig. 1).

This specimen (No. 936) is from Pridmouth, and although very much crushed is evidently a portion of a rapidly expanding Nautiloid shell. It is 37 mm. long, 60 mm. wide at its anterior, and 35 mm. wide at its posterior end. It is entirely septate, seven chambers being visible; these are shallow, and vary in depth from about 4·5 mm. at the posterior end to about 6 mm. at the anterior end. The specimen is decidedly curved, the concave or inner portion being uppermost in the view represented in Fig. 1. As seen at the edge of the specimen the septa pass obliquely backward in crossing from the concave to the convex side, and this obliquity of the septa brings into view the septal surface at

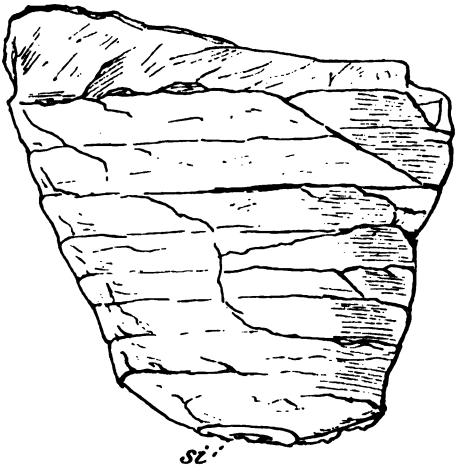

FIG. 1.—*Cyrtoceras sp.* (Middle?) Devonian, Pridmouth, Cornwall. *Si*, siphuncle. Drawn of the natural size from a specimen in the Penzance Museum (No. 936).

the posterior end, showing the rather large and apparently nummuloidal siphuncle (*si*) near the convex surface of the shell. The specimen appears to be merely a portion of an internal cast, but near one edge there are some very fine somewhat irregular transverse lines, which may possibly represent ornaments.

This example seems to be referable to the genus *Cyrtoceras*, as limited by Dr. Foord in his *Catalogue of Fossil Cephalopoda in the British Museum* (part 1, p. 265). It is so crushed that the form of the cross-section cannot be ascertained; it does not, however, appear to have been subtriangular as in *C. depressum*, Goldfuss,[1] but probably more elliptical as in *C. lineatum*, Goldfuss.[2] The position and size of the siphuncle, so far as can be ascertained, agree with *Cyr. depressum* rather than *Cyr. lineatum*. In the British Museum collection there is a specimen from Ivy-Bridge Quarry, near Newton, South Devon, that Dr. Foord has referred to *Cyrtoceras lineatum*, Goldfuss.

In the absence of better material it seems desirable to record the Cornish specimen as *Cyrtoceras sp. indet.* It is of Devonian, and possibly of Middle Devonian age.

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[1] For synonyms and references see A. H. Foord, *Cat. Foss. Ceph. British Museum*, part 1, 1888, p. 265.

[2] *Ibid.*, part 1, 1888, p. 267.

ORTHOCERAS SP. (FIG. 2).

This is a crushed and partly weathered example (No. 940) on the weathered surface of a piece of slate from Polruan, near Fowey, Cornwall. It is about 47 mm. long, and in its crushed state about 22 mm. wide at its anterior, and about 9·5 mm. wide at its posterior end. A portion of the body-chamber appears to be preserved, but the greater part of the specimen is septate, portions of nine chambers being visible. Owing to the crushed state of the specimen the actual rate of tapering cannot be ascertained, but this appears to have been somewhat rapid. The shell bears feeble annulations, which seem to have been oblique, and from 3 to 4 mm. apart. The whole surface, that is, the annulations as well as the interspaces, as shown by a small piece of the surface on one side (the right in Fig. 2) that is not so much worn as the rest of the fossil, is crossed by fine thread-like transverse lines, about five or six in the space of 1 mm.

Compared with Whidborne's *Orthoceras vicarii*[1] from the Middle Devonian of Wolborough and Lummaton, the present species is apparently a more rapidly increasing shell with coarser and more rounded annulations. Its sculpture closely

[1] G. F. Whidborne, *Mon. Devon. Fauna S. of England*, vol. i., part 2, 1890, p. 129, Plate XIII., ff. 3–7, 9, 9*a*, 9*b*.

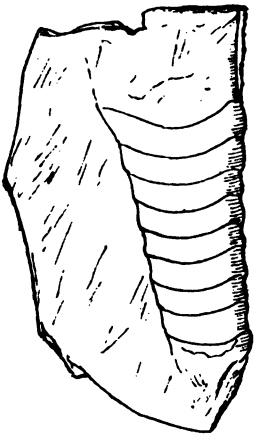

FIG. 2.—*Orthoceras sp.*, Devonian; Polruan, Cornwall. Drawn of the natural size from a specimen in the Penzance Museum (No. 940).

resembles that of *Orthoceras subannulare*,[1] which Münster described from the Upper Devonian of Elbersreuth in Bavaria, and which Mr. Whidborne has described from the Middle Devonian of Wolborough, Devon, but that is a much less rapidly tapering species. Whidborne's *O. barumense*[2] has somewhat similar ornaments, but that species also tapers much less rapidly.

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[1] G. Münster, *Beitr. zur Petrefactenkunde*, Hft. 3, 1840, p. 99, Plate XIX., f. 3. See also Whidborne, *op. cit.*, vol. i., part 2, 1890, p. 138, Plate XIV., ff. 7, 7*a*, 8, 8*a*, 8*b*.

[2] Whidborne, *op. cit.*, vol. iii., part 1, 1895, p. 30, Plate IV., ff. 7, 7*a*, 8, 8*a*, 8*b*.

GEOLOGICAL NOTES.

By Howard Fox, F.G.S.

(Read November 7th, 1899.)

Plate 16.

During the past year I have had the pleasure of spending some weeks on the north coast of Cornwall, south of the Camel, and examining some coves and foreshores not previously visited. I sent the more interesting fossils to Dr. Hinde, F.R.S., who again was good enough to consult Mr. A. Smith Woodward, F.L.S., as to the fish remains, Mr. F. A. Bather, M.A., as to the crinoids, Mr. G. C. Crick, F.G.S., as to the cephalopods, and to examine the corals and the doubtful forms himself, and to report the result. One or more entirely new forms were discovered at Bedruthan Steps. The variegated slates of Watergate Bay yielded excellent structure in Pteraspis plates and other fossils.

It was my intention to visit the various islands lying off that coast, but during my holiday month, September, there was not a single day on which it would have been prudent to attempt a landing on either of the Quies group or the Bull Rock, off Trevose Head. A brief visit was paid to Gulland Island, and sections of the rocks were

1. *nat size.*

3. × 3

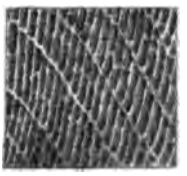
2. *nat. size*

6. × 10.

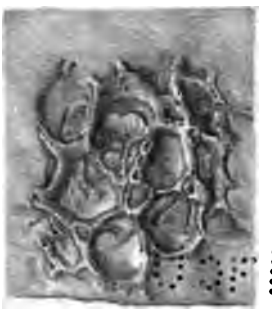
4. *nat. size.*

5. *nat. size.*

7. *nat. size*



8. × 5



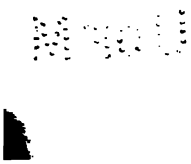
11. *nat. size.*

9 *nat. size.*

10. × 5

G. M. Woodward del. et lith. West, Newman imp.

Fossils from the Devonian Rocks.
of the North Coast of Cornwall.



sliced for the microscope and kindly described by Lieut.-General McMahon, F.R.S.

During the early spring the Gunwalloe and Mullion districts on the south coast were visited shortly after some severe storms had denuded the foreshores of most of the sand and shingle which generally cover them. Some strata were exposed with numerous black markings, suggestive of plant remains. Mr. J. H. Collins, F.G.S., and Mr. Upfield Green, F.G.S., have placed in your museum some specimens from these rocks, which by careful manipulation have shown sufficient structure to enable them to give provisional names to some of these organisms. Mr. E. T. Newton, F.R.S., has recognised another as a fossil, probably a *Nematophycus*. We will refer to the various localities, beginning with the most northern.

GULLAND ISLAND.

This island is rightly coloured greenstone on the map of the Geological Survey. It is about a quarter of a mile long, with much-indented precipitous cliffs at the north-eastern end. The south-western end has a more gradual ascent, and is sparsely covered with vegetation, as is the summit of the island. The entire island is covered with angular weathered fragments, which have jointed off the main rock, and this process is still going on fast, so much so that in climbing about one has to take care not to rely on the stability of the jutting pieces of rock. All the rocks within

reach of the waves or the spray weather nearly black, and above these they weather a rusty brown. Occasional veins and patches of calcite occur throughout.

In ascending from the southern side I found the lower cliff to be composed of a coarse-grained felspathic rock (spec. No. 679), reminding one of the altered dolerite on the north side of Permissen Beach, described in a former paper.[1]

General McMahon describes this rock thus:—

"No. 679. This is a holocrystalline felspathic igneous rock. The slice is composed of plagioclase felspar, apatite, quartz, chlorite, calcite, and a little iron ore, probably limonite.

"The plagioclase is not at all fresh, but judging from the angle of extinction, it appears to be oligoclase-andesine.

"The quartz is in idiomorphic crystals; chlorite and calcite are abundant.

"The rock has suffered very much from aqueous alterations; it must also have been subjected to pressure somewhat late in its history. This is shown by the twinning planes of some of the felspars and calcites being bent."

Further up the island we find a smaller-grained rock, but it is not easy to determine the boundaries of the respective varieties because they weather alike. Specimen No. 680 represents this second

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[1] "Notes on the Cherts and Associated Rocks of Roundhole Point, etc.," *Trans. R. Geol. Soc. Corn.*, vol. xi., p. 693, slide 321.

rock, and No. 681 represents the less altered rock forming the prominent crags and summit of the island. These specimens are thus described by General McMahon :—

"No. 680. A highly-altered felspathic igneous rock. It contains a good many pseudomorphs after felspar. The remains of binary and multiple twinning are still to be made out, but the exact species of the felspar cannot be determined. The crystals exhibiting twinning are plagioclase. The rock was apparently composed mainly of lath-shaped crystals set in a felspathic ground mass. Much of the felspar has been converted into a perfectly opaque substance, white in reflected light. If the rock ever contained any ferro-magnesian minerals they have been altered out of recognition.

"Besides the remains of felspar the thin slice contains chlorite, calcite, apatite, and pseudomorphs after iron ore, probably ilmenite.

"No. 681. I should call this a diabase. The slice is composed of a felspathic ground mass, in which augite, apatite, titaniferous iron ore, and magnetite occur with chlorite which is abundant.

"The augite is fairly fresh, and is pale coloured in transmitted light. It often crystallises on, and partially encloses, prisms of felspar.

"The whole of the felspar is saussurized and converted into a semi-opaque substance white in reflected light. Lath-shaped prisms of felspar are common, and the remains of triclinic twinning can just be made out."

The vegetation on the island consists principally of the following plants:—*Lavatera arborea* (tree mallow), *Beta maritima* (sea beet), *Atriplex patula* (spreading orache), *Crithmum maritimum* (samphire), *Arenaria marina* (seaside sandwort).

PADSTOW HARBOUR.

Both north and south of the Camel cup corals and crinoidal remains were found, but with a few exceptions the structure was indistinct.

TREVONE.

Your Council in your *Transactions* of 1894 were pleased to print my paper "On some Fossils from the Coast Sections in the Parishes of Padstow and St. Merryn." I fully expected that during the six years which have elapsed since that paper was written many fresh fossils would have been exposed by the action of the ceaseless scour of the waves and sand on the rocks. This, however, was not the case, and nothing new was found.

NEWTRAIN BAY.

In this bay I have since found two species of *Favosite* corals. West of the bay fragments of crinoidal arms were determined by Mr. F. A. Bather, M.A., Brit. Nat. Hist. Museum, to be of a somewhat similar character to those of the genus *Scaphiocrinus* (see Whidborne, *Pal. Soc.*, 1898, vol. iii., part iii., pp. 228–232, Pls. xxxi., xxxiii.–xxxviii.)

MOTHER IVEY'S BAY.

At the east end of this beach, near high-water mark, a shelf of blue shale was exposed, in which occur joints of crinoidal stems, small pyritized forms of *Tentaculites*, also a single pyritized example of a small Brachiopod *Centronella*, all of which occur at Trevone, and a pyritized specimen of *Hyolithes*.

CONSTANTINE BAY.

This district yielded some imperfect specimens of the peculiar *Conularia* described in the former paper, and but little else of interest.

PORTHCOTHAN COVE.

This cove is about three miles south of Trevose Head. In its beautiful sand, its bold cliffs, its arched rocks, its caves and islands, it reminds one of the scenery of Bedruthan Steps and Kynance Cove.

No reference appears in your *Transactions* to this cove as a fossiliferous district, but it has some interesting specimens. The general dip of the strata is E.N.E., at angles from 15° to 20°.

Dr. Hinde thus describes the organisms I sent him:—"The fossils at Porthcothan are in beds of bluish shale of a similar character to that at Trevone, Constantine Bay, and other places on the same coast. No calcareous materials seem to be present in the shale. The fossils are for the most part in very poor preservation, so that exact

determination of their characters is not practicable. The following list includes those which could be recognised :—

"*Petraia.* Examples of small, simple cup corals are not uncommon ; they are in the form of casts showing the septa and outlines of the cup, but no specific details are preserved. It is probable that two species are present, and one of them may be *Petraia celtica.*

Pleurodictyum (Pl. 16, fig. 11). The specimens are compound corals, weathered out on the surface of the shale, and in general appearance they remind one of forms belonging to this genus in the Devonian rocks of the Eifel and North America. They are comparatively small, from 20 to 24 mm. across ; there are from 7 to 10 polygonal corallites, from 5 to 8 mm. in width each, with occasionally young forms budding from the interspaces between the larger. The corallites are short and shallow, their walls apparently vesicular, and their floors with short, blunt spines.

"*Conularia.* Imperfect fragment of a form similar to those mentioned from Constantine Bay in the paper of 1894.

"*Trilobites.*[1] Two poorly-preserved pygidia or tails, with one or two body segments, were met with, but they are insufficient for generic identification.

[1] A Trilobite, minus the head, which I have recently obtained here, has been determined by Dr. H. Woodward to be a species of *Phacops.*

"*Orthoceras* and *Goniatites.* Imperfect specimens of both these genera. They are not common."

PORTH MEAR.

This cove is half a mile south-west of Porthcothan. There are here several fossils of the same character as at Porthcothan, such as *Petraia*, *Pleurodictyum* (Pl. 16, fig. 11), and, doubtful, *Orthoceras*. There are several distinct fossiliferous horizons in this foreshore. One of them extends for about 40 yards nearly due east from the north end of the island, and has numerous specimens of *Pleurodictyum* weathered out on the surface of the rocks.

LOWER BUTTER COVE.

This also is a new locality for fossils. It lies about half a mile south-west of Porth Mear. Here we find huge blocks fallen from the cliffs above, some of which are full of organic remains, among others *Petraia*, *Pleurodictyum*, and *Conularia*.

The base of the eastern cliff of the southern inlet at low water shows several of the above fossils *in situ*. I also found here a fragment of a new form, described below under the name of *Pteroconus mirus*.

BEDRUTHAN STEPS.

Bedruthan Steps has long been recognised as a fossiliferous district, and reference to it appears in your *Transactions* and elsewhere.

Mr. S. R. Pattison in 1848 writes thus in your 7th volume, page 48 :—

"The cliffs at Bedruthan Steps are composed of rock having a slight dip to the south. . . . In some blue, soft, slaty beds there are large *crinoidal* remains, a bivalve shell, other impressions, and one in particular which is much like a *Trilobite* from the Llandeilo Flags. A careful search at low water would repay the observer, and the extremely picturesque character of this lonely coast would alone furnish him with a reward for his toil."

Mr. W. Pengelly, at page 391 of the same volume, has the following reference:—

"The two species of sponges belonging to the genus *Steganodictyum* of Professor McCoy, occur in the slates along the entire coast of Cornwall from Fowey Harbour to the Rame Head, at Bedruthan Steps in the north of the same county, and at Mudstone Bay, near Brixham, in South Devon, but have never been met with in calcareous strata."

Sir Archibald Geikie, the present Director-General of the Geological Survey, in a letter to me in 1895, writes:—

"I heard from Mr. W. Winwood, of Bath, that he has lately found some remains of fossil fish (*Coccosteus*, etc.) at Bedruthan Steps. Would it not be possible to track this fossiliferous band? If we could connect it with the strata that yielded the fishes to Peach at Looe, what a capital point that would be in working out the structure of your county."

Bedruthan Steps is certainly a most interesting

locality to the fossil hunter. Huge blocks are constantly falling from the high cliffs, and some of these come from fossiliferous beds inaccessible to the climber. The rocks *in situ* are also in certain places crowded with organic remains, some of which are in fair preservation.

Some years ago Dr. Hinde was kind enough to examine some specimens I sent him from this region, and he reported that they contained the following fossils :—

A portion of a fish plate belonging to the genus *Scaphaspis*. Determined by A. Smith Woodward, F.L.S.

A portion of a ganoid fish. Determined by Mr. Smith Woodward.

A fragment of a fish plate (?).

Basal plate of the cup of a crinoid similar to *Sphærocrinus*. Identified by Mr. Bather.

Michelinia.

Pleurodictyum.

Aulopora.

Crinoidal stems of *Rhodocrinus* or *Melocrinus*, etc.

Several Zaphrentoid cup corals.

Lophophyllum (?).

Z. calceoloides (?), Champernowne. Cf. *Q.J.G.S.*, 1884, p. 497, Pl. xxi., figs. 1*a*, 1*b*, and fig. 6.

Campophyllum (sp. ?), Champernowne.

Cf. *Q.J.G.S.*, 1884, p. 498, Pl. xxi., fig. 2.

Gasteropod. *Murchisonia* (sp.?).

Orthoceras (?).

On the specimens I sent him last month Dr. Hinde reports as follows :—

"*Petraia* are present.

"There are several fragments of crinoidal remains which have been kindly examined by Mr. F. A. Bather, M.A., of the Brit. Nat. Hist. Museum, and he reports that one specimen is a cast of the anal tube of a *Dicyclic inadunate crinoid.* Another is probably a plate of a crinoidal cup, having a long slender spine attached.

"A fragment of a *Monticuliporoid.*

"*Pteroconus mirus*, Hinde (=*Nereitopsis*, Green). Pl. 16, figs. 1–4."

The fossils proposed to be included under the above name are elongated, conical, somewhat compressed tubes, with a shelly exterior test transversely or obliquely striated, having on either side at intervals small flap, or fin-like shelly extensions. The tube has a longitudinal solid axis.

There are several examples of the form weathered out in various degrees on the surface of a bluish, shaly rock, and a detailed description of the best-preserved will help in understanding the generic characters.

The most complete specimen, which is represented on fig. 1 of the plate, is a gently tapering cone, 35 mm. in length; the upper margin, apparently perfect, is evenly curved, and, including the lateral flaps, is about 9 mm. in width. The

outer surface has very delicate concentric arched lines of growth, and at intervals of about 2·5 mm. the central tube is crossed by more strongly pronounced arched lines, which, on either side of it, extend downwards, and form the anterior margin of small, flattened, or concave flaps or processes, which project about 2 mm. on either side of the central tube in its upper portion, and 1·5 mm. near the point. There are about 16 of these lappets in this specimen; they are disposed so that the posterior margin of each dips slightly under the front edge of the one next below it in the series. The terminal three or four processes appear to have coalesced together so as to form a narrow continuous plate, which extends round the end of the cone.

In another specimen, 31 mm. in length (Pl. 16, figs. 2, 3), neither the summit nor the base is complete. It is weathered out on the surface of the same kind of rock as the preceding, and a joint in the shale cuts across it obliquely and divides it into two parts. The upper portion shows the exterior surface of the central tube with lateral processes, the same as in the preceding, but the flaps in this have an upward direction, and they are distinctly marked with horizontal or upwardly directed oblique striæ. Just below the line of fracture the specimen is more weathered so as to expose the interior of the central cone, in which there is a narrow longitudinal axis with thickenings at intervals, and with elongate depressions on either

side. Outside of these depressions is the wall of the cone with the processes, which are distinctly striated, the striæ having an obliquely upward direction (Pl. 16, fig. 3). The lower margin of each flap extends to the narrow central axis. There are 17 of the flaps or processes in this specimen, and they are nearly 3 mm. apart.

The appearances presented by the horizontal or upwardly directed lateral processes in this specimen are in marked contrast with those in the forms mentioned above, where they extend downwards, and they would at first sight indicate specific differences, but Mr. G. C. Crick, who has, at my wish, carefully examined the specimens, suggested that these different aspects may arise from the way in which the lateral processes are viewed: whilst on one side they extend downwards, on the opposite side they seem to extend upwards. I therefore consider that the specimens just described belong to one species, for which I propose the name of *Pteroconus mirus*. It is possible that one of the specimens represented by Mr. Upfield Green in the *Transactions* of last year, p. 227 (Pl. F, fig. 4), may be the same as this species, but Mr. Green has stated that his larger specimen (Pl. F, fig. 1) differs from the others, being terminated posteriorly by a tuberculated extension, and to this the specific term "*cornubicus*" may be applied. Another specimen of *Pteroconus mirus*, not figured on the plate, measures nearly 3 inches long.

MAWGAN PORTH.

There are blue slates on the northern foreshore which show indications of organic remains, and some large blocks of similar rock on the south-west foreshore contain some cup corals and other fossils.

WATERGATE OR TREGURRIAN BEACH.

This range of beach and cliffs extends some 2¼ miles north of St. Columb Porth, and is noted for its variegated slates. Similar rocks occur between Fowey and Polperro, and Mr. W. A. E. Ussher, F.G.S., says that they are found in South Devon, and are known as the "Dartmouth and Kingswear Slate Group."

Prof. Sedgwick, in his paper, "On the Slate Rocks of Devon and Cornwall," wrote:—

[*Q.J.G.S.*, Feb., 1852, vol. viii., p. 4.]

"Guided by Sir H. De la Beche's notes, I found a highly fossiliferous group extending from New Quay to Mawgan Porth and Padstow, and thence to Tintagel, and not merely ranging near the coast, but running far up the interior of the country, until in some instances it approached a central boss of granite."

The only specific mention of Watergate Bay that I can trace is by Mr. Pattison in your 7th vol. of *Transactions*, page 49:—

"The cliffs are formed of variegated strata of

purple, fawn-coloured, yellow and white sandstones. The colours are so marked as to be distinctly visible across the bay from the Towan Head in the light of the setting sun. There are organic traces in the purple slates, and they are also intersected by mineral veins."

Mr. Rupert Vallentin gave me a fragment of a fish spine from this bay a few weeks ago, and this induced me to examine the cliffs minutely.

I found indications of fossils throughout the entire range of variegated rocks, but only occasionally is sufficient structure preserved to indicate the genus of the organism.

Plates of *Pteraspis cornubica*, McCoy, sp. (Pl. 16, figs. 7, 8), occur not unfrequently in satiny grey, soft shales in the cliffs both north and south of the stream that runs to the sea a little north of the noted Watergate elvan, as also in a bed of soft blue shale, dipping north.

Phlyctænaspis, sp. Pl. 16, figs. 5, 6.

Mr. Smith Woodward states that owing to the incompleteness of the plate it is not possible definitely to identify this specimen, but the tubercular surface is approximately similar to that of the plates of *P. acadica*. This genus is characteristic of the Lower Old Red or Lower Devonian.

Climatius, sp. Pl. 16, figs. 9, 10.

According to Mr. Smith Woodward the structure of this spine resembles that of the spines of the genus *Climatius*, Ag., which has a dermal spine in

front of each fin except the caudal. This genus is also characteristic of Lower Devonian rocks.[1]

At the extreme northern boundary of the bay I found a perfect and delicate fragment of a crinoidal stem in blue shale.

GUNWALLOE.

At the southern end of Loe Bar, west of the Lizard peninsula, is Gunwalloe Fishing Cove, and below the Coastguard Station on that cove and further west towards Baulk Head there are to be seen on the foreshore, at certain seasons when the shingle has been removed by storms, some strata of blue and grey argillaceous slates with peculiar black markings and other indications of fossil organisms.

The same appearance may be traced at intervals in the rocks of the foreshore for over a mile south until we reach the Castle promontory, which bounds Gunwalloe Church Cove on the north, but nowhere are the markings so abundant as in the rocks on the south side of the Fishing Cove.

These markings bear some resemblance to plant remains, but some of our palæobotanists are unable to acknowledge them as such. I am indebted to Mr. J. H. Collins for his patient examination of these specimens. He wrote to me on the 23rd ult.:—

[1] A minute description of these Watergate fish remains appears in the *Geological Magazine* for April, 1900, pp. 148, 149.

"I find only for certain a number of pyritized fragments of crinoid stems (spec. 1,588), and what looks like a greatly crushed trilobite (spec. 1,581)."

He writes to me again on the 3rd inst.:—

"I am sending you by parcel post four more of the Gunwalloe specimens, which Mr. Upfield Green has been kind enough to work out. One looks a little like *Nereitopsis* (see last issued part of *Transactions R.G.S. Corn.*), the other three suggest to me the Silurian genus of *Polyzoans*, *Ptilodictyum*. I have put these names on provisionally, with a query in each case. Some day we shall get better specimens no doubt.

"The closest examination does not reveal fish remains, but I believe some of the thin black markings consist of plant remains, as I find free carbon present. Mr. B. Kitto, F.G.S., has been kind enough to make some quantitative tests on a fragment of the Gunwalloe slate thickly sprinkled with the dark fragments and a similar fragment of the fish rock from near Polperro.

"Of these he reports as follows:—

	Polperro.	Gunwalloe.
P_2O_5 ...	0·72 ...	0·10
C_aO ...	1·23 ...	0·72

"Thus we find very much more phosphate of lime in the fish rock than in the Gunwalloe rock.

"I am having some micro-sections prepared, which may throw more light on the subject. I believe these are the oldest fossils yet found in Cornwall."

I subsequently found an organism with more decided structure above high-water mark, on which Dr. Hinde writes as follows:—

"I showed your Gunwalloe specimen to Mr. E. T. Newton, F.R.S., of the Jermyn Street Museum; he thought it was a plant, and it recalled to him the forms described under the genus *Nematophycus*, Carruthers, as an Alga. You will find a description of one of the species in the *Quarterly Journal G.S.*, vol. 37, 1881, p. 490. It came from the Denbigh Grits (=Wenlock), but Mr. Carruthers states that a form with a similar structure was found in the Gaspe sandstones of Canada of Lower Devonian age, and named by the late Dr. Dawson *Prototaxites*. It is very doubtful, owing to the pyritized condition of your specimen, whether it would show anything were a section made of it."

POLURRIAN COVE.

This foreshore is at ordinary times covered with sand, but on the 15th March last the larger portion was exposed rock. There was sand at the foot of the cliff below the Polurrian Hotel, and a triangle of sand extended from the sea at dead low water, with its apex in the middle of the cove.

On the north side there was a continuous large area of shale of the same character as that in the cliffs above. This was followed by hard, purple

silicious schistose rock, veined with quartz, with prominent blocks of white felspathic and quartz rocks towards the middle of the cove. To the southward of these came an interesting series of fault breccia rocks, rounded by the scour of the sand, and amongst them were large blocks of quartz and quartz breccia, the whole weathering for the most part a rusty brown colour, and running about south from the well-known junction in the cliff. Some of the exposed rocks and boulders were over 6 feet high, so that at least 8 feet of sand had been carried seaward by the waves.

Description of Plate 16.

Fig. 1. *Pteroconus mirus*, Hinde. Natural size.
Fig. 2. „ „ „ „
Fig. 3. Enlargement of part of Fig. 2.
Fig. 4. *Pteroconus mirus*. Natural size.
Fig. 5. Fish Plate approximately similar to those of *Phlyctænaspis acadica*, Whiteaves. Natural size.
Fig. 6. Enlargement of part of Fig. 5.
Fig. 7. Fragment of plate of *Pteraspis cornubica*, McCoy, sp. Natural size.
Fig. 8. Enlargement of part of Fig. 7.
Fig. 9. Fish spine allied to the genus *Climatius*, Agassiz. Natural size.
Fig. 10. Enlargement of part of Fig 9.
Fig. 11. *Pleurodictyum* sp. Natural size.

The three specimens of *Pteroconus mirus* and the *Pleurodictyum* figured in this Plate are in the Natural History Museum, South Kensington. Casts of these *Pteroconus* are in your own Museum with other specimens of this genus, including one 72 mm. long by about 6 mm. broad. Several specimens of *Pleurodictyum* similar to Fig. 11 are also in your Museum.

Royal Geological Society of Cornwall.

THE EIGHTY-SEVENTH

ANNUAL REPORT

ETC.

PENZANCE
1901.

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THE

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JOHN DAVIES ENYS, ESQ., F.G.S.,

To the General Meeting, November 13th, 1900.

LADIES AND GENTLEMEN,—The Council of the Royal Geological Society of Cornwall have this year awarded the Bolitho Gold Medal to Dr. Le Neve Foster, D.SC., F.R.S., Inspector of Metalliferous Mines for North Wales.

I am glad to say he has kindly visited us to receive the Medal himself, and I think we may all cordially welcome him to Cornwall, where he is so well known; indeed, his name is attached to the fences he was one of the main causes in having erected round the mouths of old mine shafts.

In the list of papers published by the Royal Society Dr. Le Neve Foster's name is entered with a long list of valuable papers from 1865 to a late period.

The papers which concern us most in Cornwall are those on mines and minerals relating to the county.

In 1866 the Report of the British Association contains at pages 36 to 52 an account of "A Curious Mineral Vein at Rosewarne Mine."

In the 1877 Report of the British Association is a paper "On the great flat lode S. of Redruth and Camborne, and on some other tin deposits formed by the alterations due to Granite."

In 1866 the *Geological Magazine* contains a paper "On the occurrence of Molybdenite in Leicestershire and of Linavite in Cornwall."

In 1878 "On some tin stock-works in Cornwall."

In 1875 "Notes on Haytor Iron Mine."

In 1877 "On some new Mineral localities in Cornwall and Devon."

Dr. Foster's *Text Book of Ore and Stone Mining, 1900,* has reached a third edition, and needs no word from me of commendation.

Dr. Foster has also published papers on "Balleswidden," "Wheal Mary Ann," "Prosper," "Michel," etc.

Dr. C. Le Neve Foster's connection with the Royal Cornish Geological Society will be remembered by many of you as Curator here, and he was also Secretary to the Polytechnic and connected with the Royal Institution.

Before handing Dr. C. Le Neve Foster the Medal, I must refer to the occasion on which he risked his own life in assisting to preserve the lives of miners confined in a mine in the Isle of Man, and the painful experience he underwent on that occasion.

Having reached the last year of the nineteenth century, it may be of interest to recall some of the leading dates in the history of the science of Geology.

Thanks to the book recently published by Sir Archibald Geikie, in 1897, I can give shortly many points of interest, and draw your attention to the different men who first placed the science on a proper footing.

In the year 1692 John Ray, or Wray as he was first known as, publishes his *Miscellaneous Discourses,* and points out the great denudation that is constantly going on, and even suggests that the whole earth might in time be reduced to a level with the sea.

In 1699 Edward Lhuyd records and describes a trilobite from the Dudley beds, amongst other fossils.

Sir A. Geikie informs us that the earliest map coloured to show the geology of the country was published at Leipzig, in 1778, by J. F. Charpentier, and that eight tints were used by him. To Martin Lister, however, is to be credited the first

proposal to depict on a map the distribution of mineral products of the earth. On March 12th, 1683, he delivered to the Royal Society of London a paper under the name of "An Ingenious Proposal for a New Sort of Maps of Countries, together with tables of sands and clays, such chiefly as are found in the north parts of England, drawn up about ten years since, and delivered to the Royal Society March 12th, 1683, by the learned Martin Lister, M.D., Ph. Tr. xiv. p. 739."[1]

Works on the theory of the formation of the earth were published by Leibnitz in 1749, and Buffon in the same year.

To P. S. Pallas, 1741–1811, are due the names tertiary and secondary formations, while to M. de Saussure is due the name of Geology for the science, as against the older form of Cosmology formerly in use. The word Geology was long in coming into use, and is not found in the edition of the *Encyclopædia Britannica* published in 1800, only a hundred years ago.

The geologists of the last century early divided themselves into the Vulcanists and Neptunists, so called from the one school trying to force all facts into a proof that the earth, as now existing, was formed by the action of heat, while the others did the same to prove that water was the sole, or nearly so, cause of the same.

The early observers soon noticed that there was a sequence in the beds in which certain fossils were found, and Sir A. Geikie gives the credit of early discoveries in this direction to Jean Etienne Guettard, 1715–86; Johann G. Lehmann, *d.* 1767; and Nicholas Desmarest, 1725–1815.

J. E. Guettard was one of the founders of Palæontological Geology; he by his study of rocks in the field was led to suppose that they followed certain lines of sequence. He described three bands of formations surrounding Paris, and

[1] The earliest map I have met with of the western counties which is shaded to represent the geological features of Somerset, Dorset, Devon, and Cornwall is published by William George Maton, M.A., in 1797, in his "Observations relating chiefly to the Natural History of the Western Counties of England made in the years 1794 and 1796."

to the third he gave the name of "schistose," or metalliferous; he placed symbols on a map to denote where certain minerals were to be found, and used shading to separate the formations known to him. He also pointed out the formations he knew on the north coast of France, which reappeared in England on the south coast, and were joined under the Channel. Guettard was the first to discover trilobites in the Silurian slates of Angers, and to him are to be credited the discovery and description of the old volcanoes of the Puy de Dôme in Auvergne.

Nicholas Desmarest, 1725–1815. His first essay was sent in for competition for a prize proposed by the Duc de Chaulnes in 1753, as to the former connection between France and England, and led to his becoming known to D'Alembert and others.

In 1763 he explored Auvergne, and studied the formation of basalt, so called by Pliny.

It had actually been suggested years before that its jointed form might arise from its having formerly been bamboos, turned into stone.

A long war was waged over its history, and its origin by water and by heat had both their advocates.

Desmarest, after careful observation in the Puy de Dôme district, practically proved their volcanic action, but was met with a storm of criticism from his opponents.

Headed by Werner, the advocates of the formation of basalt by water and chemical action delayed the acceptance of its true formation for years.

To Pierre Simon Pallas, 1741–1811, are due a long account of the Geology of Siberia, and the account of the remains of the mammoth preserved in superficial deposits in that country.

He described the mountain-chains of that country, and brought them within the compass of knowledge, pointing out the absence of life, as shown by no remains occurring in the highest of the ranges, which are of granite, serpentine, and grits.

Limestones are placed as secondary, being much upheaved by the older rocks.

The lower and much more fossiliferous limestones are called tertiary rocks, thus starting that name now so well known.

Johann G. Lehmann, *d.* 1767. To Lehmann is to be credited the first important work (published at Berlin, 1756) pointing out the succession of the rocks forming the crust of the earth.

George Christian Fuchsel, 1722–73, continued Lehmann's work with more accuracy of detail.

Under Abraham Gottlob Werner, born 1749, died 1817, who appears in 1815 as an Honorary Member of this Society, Sir A. Geikie places on record his opinion as follows, p. 103 :—

"He did great service by the precision of his lithological characters and by his insistence on the doctrine of geological succession, yet, that as regards geological theory, whether directly by his own teaching, or indirectly by the labour of his pupils and followers, much of his influence was disastrous to higher interests of Geology."

He taught that the earth was originally clothed with water as high as the highest mountains now existing, and that the primitive rocks were all formed by chemical action.

He included in his primitive formation granite, which was the oldest, gneiss, mica-slate, basalt, and he put syenite at the bottom.

In the transition rocks greywacke limestone, which indicated a lowering of the water.

In the floetz rocks he states the rocks were chiefly of mechanical sediment, but partly also of chemical formation.

Last of all he placed the alluvial formations, consisting of sandstones, gypsum, coal, basalt, obsidian, and porphyry.

What became of the water when it retired he never accounted for, but stated it retired, and his followers had to be contented with that.

He was the principal supporter of the chemical formation under water of almost all rocks, including granite and basalt. When it was shown that granite veins ran into what are now known as tertiary rocks, it was at once taken to prove that these rocks were as old as his first-formed group of rocks. Basalt was also taken to be a water-formed rock, and no proof was allowed to change this belief.

In Robert Jameson, 1774–1854, the Wernerian theory found

a warm advocate, and to him is to be credited the hold it obtained in Edinburgh. The great battle about the formation of basalt was one of the most lasting of the effects of Werner's teaching, and Jameson took a leading part in it and delayed the true facts of its origin being accepted.

James Hutton, 1726–97. Hutton was one of the first to show that a number of so-called water-formed rocks were only to be explained by their being forced up through existing formations, and did much to upset much of the theory put forth by Werner. In fact he showed the formation of such rocks must be of the nature of volcanic forces.

William Smith, 1769-1839. Smith was born in Oxfordshire, and by his work in recognising that certain formations were always found above others, that they were distinguished by a distinctive set of fossils, and that, however different the strata might appear, they might be determined by the careful collection of the forms of shells and plants contained in them, finally paged the book of nature, and placed in the hands of all future explorers the key by which to determine the formations they met with.

This index to the book of nature has proved to be of universal application.

Smith's map was published in August, 1815, having been begun in 1813, and embodies the work of many years. Smith is well known under the name of the "Father of Geology," and well deserves the name.

I now come to men well known to many living, and shall pick out a name or two of those who are typical of certain advances in the science of Geology.

Adam Sedgwick, 1785–1873, is a name for ever associated with the Cambrian formations which he did so much to unravel in North Wales. One of his earliest papers was on the "Rocks of Devon and Cornwall," which brings him in direct touch with this county.

His work in tracing the Cambrian rocks from their lowest beds up to and overlapping the work of Sir R. Murchison in South Wales is the work by which he is so well known.

Sir Roderick I. Murchison, 1792–1871. To Murchison is due the mapping out of the Silurian strata in South Wales and parts adjacent.

Murchison and Sedgwick both started their work in Wales in the same year, and their work overlapped and led to disputes as to where the Silurian and Cambrian meet.

Murchison also did good work in the Scotch formation of old date; he also published papers on the Alps and the Ural Mountains of Russia.

As typical of the theory of the Glacial Period Jean Louis Agassiz must be quoted, living from 1807–73. He first proved the value of the Glacial Period in explaining part of the life-history of the world. Agassiz is also well known for his great work on fossil fish.

William Nicols was the first to cut thin slices of fossil wood, and showed that the structure could be thus studied. His slices of rocks, after being practically placed on one side, fell under the view of Henry Sorby, and led to the publication by him in 1858 of the memoir named *On Microscopical Structure of Crystals*, the practical foundation of Petrographical science, which has made us acquainted with the structure of volcanic rock in particular, and enabled those rocks to be classified with certainty.

Sir Charles Lyell, 1797–1875. Sir C. Lyell's work on the elements of Geology had a great influence in showing how in many cases the present influences at work on the earth would, if only time were allowed, account for the formation of the past strata of the earth.

Charles R. Darwin, 1809–82. The name of Charles Darwin is written large in the annals of the nineteenth century as one who by the careful collection of facts, and the acute reasoning from them, has given an impetus to Geology as well as Natural History, and the publication of the *Origin of Species* in 1859 marks a date not to be forgotten.

On May 28th, 1856, I had the great pleasure of hearing him read a paper at the Geological Society Rooms in Somerset House on the formation of deposits at the bottom of the sea by the discharge of water carrying mud in suspense, showing how the

heavier part would sink first, while the lighter parts would be carried far away and form a fine sedimentary deposit.

Joseph Prestwich, 1812–96. Prestwich's name is associated with the latest form of geological deposits, which were for a long time all classed as modern, and to him is due, amongst others, the proof that they can be separated and shown to have been formed at many different periods.

To French geologists is due the finding the earliest traces of the works of man in the old river gravels of that country.

Robert Etheridge. I cannot pass the name of our first medallist, Etheridge, without alluding to his great work on fossils. I feel proud of his connection with this Society.

Workers in Cornish geology have been numerous, and include such names as William Borlase, Sedgwick, Sir H. Warington Smyth, Henwood, Carne, our present medallist, Le Neve Foster, Howard Fox, Robert Were Fox, in his own department of Mineral Veins, C. Peach, Pengelly, and Sir Henry Thomas De la Beche.

In this short sketch from Sir A. Geikie's book I must not pass over the names of those who have done so much to describe the animal and other remains preserved in the rocks of the world. First of many in England I must allude to those of Gideon Mantell in Sussex, Robert Etheridge, William Buckland, Sir Richard Owen, and many others, while France has the name of Cuvier to head her list of great names in this science.

America can also claim her full share, associated with Marsh amongst others.

In concluding this slight sketch of some of the eminent names of those who have done good work in Geology, I have not attempted to do more than name a few of those who have left their mark in the science, and taken in the latter stages only one of many names representing certain advances in it.

REPORT OF THE COUNCIL

To the General Annual Meeting, November 13th, 1900.

In their last Report the Council expressed the hope that a continuation of the good price of tin would lead to a speedy revival of the great industry of Cornwall. To those living in Cornwall who know the enormous quantity of mineral still waiting under our feet for the attack of the miner's tools, and who are acquainted with the districts where the great mineral wealth is to be found, it is simply astonishing that the past year has seen so little enterprise in the reworking of our local mines. We still hope, and those hopes are, if anything, strengthened by the passing of time, for it seems almost impossible that with enormous sums of capital seeking for investments the great mineral wealth of this county could be much longer left unprofitable and undisturbed.

This Society has for many years enjoyed a high reputation as possessing in this museum an exceptionally rich collection of mineral specimens, which represents worthily the vast underground wealth of Cornwall, and the Council feel that the members may well take an equal pride in the collection of fossils. Thanks to the labours of Mr. H. Fox and Mr. J. H. Collins, and the assistance which those gentlemen are receiving from Dr. Hinde, F.R.S., Mr. A. Smith Woodward, Mr. Upfield Green, and Dr. Bäckstrom, the collection of Cornish fossils in the lower museum is not only superior to anything of the sort in Cornwall, but is rapidly attaining a reputation which extends far beyond the limits of the county.

The annual joint meeting of the Cornish Scientific Societies

at Falmouth in August was made especially interesting by the visit of Mr. James Stirling, the President of the Geological Society of Australasia. In the summer your Secretary received a communication from the Agent-General of Victoria to the effect that Mr. Stirling was visiting England, with the authority of the Government of the Colony, to bring all information of the mineral wealth of the Colony before the notice of the English public, and that for this purpose Mr. Stirling was anxious to be allowed the opportunity of meeting as many persons interested in mining and Geology as possible. The meeting afforded such an opportunity, and Mr. Stirling readily accepted the invitation of this Society to attend. Arrangements were then made for a further visit, and it was hoped that you would have had the pleasure of meeting Mr. Stirling here to-day; but he is unfortunately unable to come so far west at this time, and the Council have therefore invited him to come at some later date to deliver a lecture in this museum. If this proposal is carried into effect due notice of the arrangements will be published.

The library of the Society has been added to during the past year by the publications of all the numerous Societies from every part of the world with whom we are pleased to be allowed the privilege of exchange. But an especial addition to the shelves has to be recorded. Mrs. Rolleston, of Sevenoaks, has most kindly presented to the Society five volumes of MSS. of Sir Humphry Davy, containing five of those lectures delivered by him before the Royal Institution which did so much to give a lustre to his name; and also five volumes of MSS. of his brother, Dr. John Davy, containing the records of his voyages to the Mediterranean, the Cape, and the West Indies. In addition to the accounts of the voyages and the descriptions of the places visited, these MSS. contain many valuable notes and statistics of scientific value, notably those relating to the temperature of the human body and the bodies of animals. The thanks of the Society are, the Council feel sure, heartily tendered to Mrs. Rolleston for such interesting and valuable presents.

The want of shelf room in the Library, which was felt two years ago, was got over at that time by a rearrangement of some of the books, but it is now again becoming a matter of difficulty. Some of the publications, especially those from America, are increasing to such an extent that something more than any matter of rearrangement will soon be essential to provide the necessary space.

The same difficulty is making itself felt in this room. We have received during the year an interesting collection of minerals from Broken Hill, N.S.W., kindly presented by E. Skewes, and your officers are faced with a great difficulty in arranging to find a proper space for these specimens. The Society are pleased to receive these additions to the museum, and it is a matter of course that room must be provided.

The work of the new Geological Survey of the county, which was undertaken on the instigation of this Society three years ago, still continues, and Mr. J. B. Hill, the surveyor engaged in the work, will give the members at this meeting an account of what has already been done.

The portrait of Mr. Davies Gilbert, P.R.S., presented by Mr. Enys, has now been framed at the cost of Mrs. T. R. Bolitho, and will be hung in the upstairs museum. The Society are indebted to Mr. Enys and Mrs. Bolitho for the possession of such a valuable memorial of a distinguished Cornishman.

The publications of the Society continue to be inquired for, and in addition to the current issue there is a steady demand for the back numbers of our *Transactions*.

The Council have decided to award the William Bolitho Gold Medal this year to Dr. Clement Le Neve Foster, F.R.S., a gentleman who has earned the distinction by his eminent position and by the many services which he rendered to this Society in the office of Curator in the years during which he filled the office of Inspector of Mines for Cornwall and Devon. The members will give Mr. Foster a hearty welcome on his now coming amongst us once more.

The Committee are pleased to record that the Society has not

lost a member by death during the year; and they venture to add good wishes for a prosperous voyage and a safe return to one of the members, Mr. F. V. Hodgson, of the Municipal Museum, Plymouth, who is about to take part in the National Antarctic Expedition.

LIBRARIAN'S REPORT

From November 1st, 1899, to October 31st, 1900.

THE following works have been added to the Library during the year:—

I. TRANSACTIONS, JOURNALS, AND REPORTS.

Presented by the respective Societies, Editors, and other Donors, or Purchased.

Adelaide. South Australian School of Mines and Industries, and Technological Museum.

Eleventh Annual Report, 1899. Accompanied with a Geological Map of South Australia.

8vo. Adelaide, 1900.

Boston. American Academy of Arts and Sciences.

Proceedings: Vol. xxxv., Nos. 1–27, July, 1899, to June, 1900. Including Title-page, Index, and Contents of vol. xxxv.

Proceedings: Vol. xxxvi. Nos. 1–4, June to July, 1900.

Royal 8vo. Boston, 1899–1900.

Brussels. Société Royale Malacologique de Belgique.

Bulletins des Séances: Pp. 97–128. Année 1899.

8vo. Bruxelles, 1899.

Buenos Aires. Museo Nacional.

Comunicaciones: Tomo i., No. 4.

" " " 5.

" " " 6.

8vo. Buenos Aires, 1899.

Buffalo. Society of Natural Sciences.
Bulletin: Vol. vi., Nos. 2–4, May, 1898, to September, 1899. Royal 8vo. Buffalo, N.Y., 1899.

Cambridge. University Library.
Report of the Library Syndicate for the year ending December 31st, 1899. 4to. Cambridge, 1900.

Canada. Canadian Institute.
Proceedings: New Series, vol. ii., part 2, No. 8. September, 1899.
„ New Series, vol. ii., part 3, No. 9. February, 1900. Royal 8vo. Toronto, 1899–1900.

——. Transactions: Vol. vi., parts 11–12, December, 1899. Including Title-page and Contents of vol. vi. Royal 8vo. Toronto. 1899.

——. Geological Survey of Canada.
Annual Report for the year 1897. New Series, vol. x., with maps. Roy. 8vo. Ottawa, 1899.

——. Contributions to Canadian Palæontology: Vol. iv., part 1. Roy. 8vo. Ottawa, 1899.

——. Preliminary Report on the Klondike Goldfields, Yukon District, Canada. By R. G. McConnell, B.A. 8vo. Ottawa, 1900.

——. Descriptive Note on the Sydney Coalfield, Cape Breton, Nova Scotia, with maps. By Hugh Fletcher, B.A. 8vo. Ottawa, 1900.

——. Natural History Society of Montreal.
The Canadian Record of Science, vol. viii., No. 2.
„ „ „ „ 4. 8vo. Montreal, 1899–1900.

——. Royal Society of Canada.
Proceedings and Transactions: Second Series, vol. iv., May, 1898. Imp. 8vo. Ottawa, 1898.

Cincinnati. Society of Natural History.
Journal: Vol. xix., No. 5, January, 1899. Including Index to vol. xviii.
Journal: Vol. xix., No. 6, June, 1900.
8vo. Cincinnati, 1899–1900.

Colorado. Scientific Society.
Proceedings (in separate pamphlets), viz.:—
Notes on Mining and Smelting in the State of Durango, Mexico. By H. Van F. Furman. Read January 6th, 1900.
Outlines of the Theoretical Chemistry of Copper. By Charles Skeele Palmer. Read February 3rd, 1900.
8vo. Denver, 1900.

——. Bulletin: Nos. 1 and 2, 1900.
8vo. Denver, 1900.

——. College Studies: Vol. viii. Papers read before the Colorado College Scientific Society.
8vo. Colorado Springs, Colo., 1899.

Connecticut. Academy of Arts and Sciences.
Transactions: Vol. x., part 1. Including Title-page, Index, and Contents of vol. iv.
Royal 8vo. New Haven, Con., 1899.

Dorpat. Dorpater Naturforscher-Gesellschaft.
Sitzungsberichte: Band xii., heft 2, 1899.
8vo. Dorpat, 1900.

Dublin. Royal Dublin Society.
Economic Proceedings: Vol. i., parts 1–2, November, 1899.
8vo. Dublin, 1899.

——. Scientific Proceedings: New Series, vol. ix., parts 1–2, October, 1899, to March, 1900.
8vo. Dublin, 1899–1900.

——. Scientific Transactions: Vol. vii., series ii., parts 2–7, June, 1899, to April, 1900.
4to. Dublin, 1899-1900.

Dublin. Index to the Scientific Proceedings and Transactions from 1877 to 1898 inclusive. 8vo. Dublin, 1899.

Edinburgh. Royal Society of Edinburgh.
Proceedings: Vol. xxii., Sessions 1897–1899.
8vo. Edinburgh, 1900.

Falmouth. Royal Cornwall Polytechnic Society.
Sixty-seventh Annual Report, 1899.
8vo. Falmouth, 1899.

Freiberg. Jahrbuch für das Berg-und Hüttenwesen im Königreiche Sachsen auf das Jahr 1898–1899.
Imp. 8vo. Freiberg, 1898–1899.

Illinois. Augustana College and Theological Seminary.
Augustana Library Publications: No. 2. An old Indian Village. By Johan Udden.
4to. Rock Island, Ill., 1900.

India. Geological Survey of India.
General Report on the work carried on for the period from April 1st, 1899, to March 31st, 1900.
Royal 8vo. Calcutta, 1900.

——. Memoirs: Vol. xxix.
„ „ xxx., part 1.
Royal 8vo. Calcutta, 1900.

——. Palæontologia-Indica: Series xv., vol. i., part 2.
Title-page, Contents, and Appendix, vol. ii.
Palæontologia-Indica. Series xv., vol. iii., part 1.
„ „ New series, vol. i., parts 1–2.
With Plates. 4to. Calcutta, 1899.

Indiana. Department of Geology and Natural Resources.
Twenty-third Annual Report, 1898.
Twenty-fourth „ „ 1899.
By W. S. Blatchley, State Geologist.
Royal 8vo, cloth. Indianapolis, 1899.
[Presented by W. S. Blatchley, Esq.]

Iowa. Geological Survey.
Annual Report: Vol. ix., 1898. With accompanying papers. 4to. Des Moines, Iowa, 1899.

Japan. Imperial University.
Notes on the Minerals of Japan. By Kotora Jimbō, Professor of Mineralogy. 4to. Tōkyō, Japan, 1899.

Kansas. Academy of Science.
Transactions of the Thirtieth and Thirty-first Annual Meetings, 1897–1898. Vol. xvi. Royal 8vo, cloth. Topeka, Kansas, 1899.

Leicester. Literary and Philosophical Society.
Transactions: Vol. v., part 5, July, 1899.
" " " 6, October, 1899.
" " " 7, January, 1900.
" " " 8, April, 1900.
8vo. Leicester, 1899–1900.

Liège. Société Géologique de Belgique.
Annales: Tome xxiv.
" " xxv. Royal 8vo. Liège, 1898–1899.

Liverpool. Literary and Philosophical Society.
Proceedings: Vol. liii., Session lxxxviii., 1898–1899. 8vo. Liverpool, 1899.

London. British Association for the Advancement of Science.
Report of the Sixty-ninth Meeting, held at Dover in September, 1899. 8vo, cloth. London, 1900.

——. Geologists' Association.
Proceedings: Vol. xvi., parts 5–9, November, 1899, to August, 1900. 8vo. London, 1899–1900.

——. List of Members, February, 1900. 8vo. London, 1900.

——. Geological Society of London.
Quarterly Journal: Vol. lv., part 4, No. 220, November, 1899. Including Title-page, Index, and Contents of vol. lv.

London. Geological Society of London.

Quarterly Journal: Vol. lvi., part 1, No. 221, February, 1900.
" " " " 2, " 222, May, 1900.
" " " " 3, " 223, August, 1900.
8vo. London, 1899–1900.

——. Catalogue of Geological Literature added to the Society's Library during the year 1899. 8vo. London, 1900.

——. List, November 1st, 1899. 8vo. London, 1899.

——. London, Edinburgh, and Dublin Philosophical Magazine. Series v., vol. xlviii., Nos. 294–295, November and December, 1899. Including Title-page, Index, and Contents of vol. xlviii.

Series v., vol. xlix., Nos. 296–301, January to June, 1900. Including Title-page, Index, and Contents of vol. xlix.

Series v., vol. l., Nos. 302–305, July to October, 1900.
8vo. London, 1899–1900. (Purchased.)

——. Mines and Quarries.

General Report and Statistics for 1898, part 4. Colonial and Foreign Statistics relating to Persons employed, Output, and Accidents at Mines and Quarries in the British Colonies and in Foreign Countries. Edited by C. Le Neve Foster, D.SC., F.R.S. Folio. London, 1900.
[Presented by C. Le Neve Foster, Esq.]

——. General Report and Statistics for 1899. Parts 1–2.

Part 1. Statistics of the Persons employed, Output, and Accidents at Mines and Quarries in the United Kingdom, arranged according to the Inspection Districts.

Part 2. Labour: Relating to Persons employed and Accidents at Mines and Quarries in the United Kingdom, and to the enforcement of the Mines and Quarries Acts.
Edited by C. Le Neve Foster, D.SC., F.R.S.
Folio. London, 1900.
[Presented by C. Le Neve Foster, Esq.].

London. Reports of C. Le Neve Foster, H.M. Inspector of Mines for the North Wales, etc., District (No. 9), under the Metalliferous Mines Regulation Acts, 1872 and 1875, and the Quarries Act, 1894, for the year 1899.
Folio. London, 1900.
[Presented by C. Le Neve Foster, Esq.]

——. Palæontographical Society.
Vol. liii. for 1899. 4to. London, 1899. (Purchased.)

——. Royal Society.
Proceedings: Vol. lxv., Nos. 420–423, November, 1899, to January, 1900. Including Title-page, Index, and Contents of vol. lxv.

Proceedings: Vol. lxvi., Nos. 424–434, February to August, 1900. Including Title-page, Index, and Contents of vol. lxvi.

Proceedings: Vol. lxvii., No. 435, October, 1900.
8vo. London, 1899–1900.

——. Reports to the Malaria Committee of the Royal Society, 1899–1900. 8vo. London, 1900.

Manchester. Geological Society.
Transactions: Vol. xxvi., part 9, Session 1898–1899.
„ „ parts 10–19, Session 1899–1900.
8vo. Manchester, 1899–1900.

——. Geographical Society.
Journal: Vol. xv., Nos. 1–12, January–December, 1899. Including Title-page and Contents of vol. xv.
„ Vol. xvi., Nos. 1–3, January–March, 1900.
8vo. Manchester, 1899–1900.

——. Supplement to the Journal:
Vol. xi., Nos. 9–12, October–December, 1895. Including Title-page and Index of vol. xi.
8vo. Manchester, 1900.

Manchester. Manchester Museum, Owens College.

Report of the Director of the Museum for the year 1899–1900. 8vo. Manchester, 1900.

Mexico. Instituto Geológico de México.

Boletin: Num. 12–13. 4to. México, 1899.

Montevideo. Museo Nacional de Montevideo.

Anales: Tomo ii., Fasgigulo 12.
„ Tomo iii., Fasgigulo 13–14.
4to. Montevideo, 1899–1900.

Netherlands-India. Jaarboek van het Mijnwezen in Nederlandsch Oost-Indië Uitgegeven op last van Zijne Excellentie, den Minister Van Koloniën. 28th year, 1899. Technisch-en-Administratief-en-Tweede Wetenschappelijk Gedeelte. 8vo. Amsterdam, 1899.

Newcastle-upon-Tyne. North of England Institute of Mining and Mechanical Engineers.

Transactions: Vol. xlviii., part 5, issued July, 1899.
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by J. M. Clements and H. L. Smyth, with a chapter on the "Sturgeon River Tongue," by W. S. Bayley, and an Introduction by C. R. Van Hise; "The Slate Belt of Eastern New York and Western Vermont," by T. N. Dale; "The Coos Bay Coalfield, Oregon," by J. S. Diller; "The Titaniferous Iron Ores of the Adirondacks," by J. F. Kemp; "Geology of the McAlester-Lehigh Coalfield, Indian Territory," by J. A. Taff, accompanied by a Report on the "Fossil Plants," by D. White, and a Report on the "Paleozoic Invertebrate Fossils," by G. H. Girty; "Geology and Mining Industry of the Tintic District, Utah," by G. W. Tower, junr., and G. O. Smith. Part 5: "The Forests of the United States," by H. Gannett; "Black Hills Forest Reserve," by H. S. Graves; "Bighorn Forest Reserve," by F. E. Town; "Teton," and "Yellowstone Park Forest Reserves," by T. S. Brandegee; "Priest River," "Bitterroot," "San Jacinto," "San Bernardino," and "San Gabriel," Forest Reserves, by J. B. Leiberg; "Washington Forest Reserve," by H. B. Ayres; "Eastern Part of Washington Forest Reserve," by M. W. Gorman; "Forest Conditions of Northern Idaho," by J. B. Leiberg; "Pine Ridge Timber, Nebraska," by N. H. Darton. Part 5 continued: "Forest Reserves Atlas." 4to, cloth. Washington, 1899.

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[Presented by the Author.]

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DONATIONS TO THE MUSEUM.

NAME AND LOCALITY.	DONOR.
Specimens of typical Mineral-bearing Rocks from Broken Hill, Calgoorlie, Westralia.	E. Skewes.
A Cornu of Cephalaspis Carteri. . .	Upfield Green.
From Parish of St. Eval.	
Alveolites (2 specimens) from Bedruthan H.R.	Howard Fox.
Serpulites (?) „ „ „	
Spirifer „ „ „	
Fistulipora „ „ „	
Loxonema „ „ „	
Shell from Red Cove Island „	
Pterocomis mirus, nest of. Samaritan Island.	
„ „ fragment of. „	
„ „ „ „	
„ „ Mother and Child (?), from Bedruthan H.R.	
Pleurodictyum, from Diggory's Island.	
Two Cup Corals „ Pentire Beach.	
Monticuliporoid „ „	
„ „ the Saddle Beach.	
Petraia, from Boathouse Cove, Trescore.	
Conularia „ „ „	
Shell fragment, from Trescore South Island.	

TREASURER'S STATEMENT, 1899-1900.

Dr. *The Treasurer in Account with the Royal Geological Society of Cornwall.* **Cr.**

November 13th, 1900—	£	s.	d.
To Ordinary Subscriptions and Arrears	45	3	0
,, Donation per His Royal Highness The Prince of Wales	20	0	0
,, One Year's Dividend on £1,800 Midland Railway 2½% Debenture Stock, £45 0s. 0d., less tax £1 13s. 9d.	43	6	3
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,, Donation to cost of plate per Howard Fox, Esq.	2	2	0
	£112	0	9
,, Balance of Deposit Account transferred ...	45	15	1
,, Balance due to Treasurer, 1900	18	3	1
	£175	18	11

November 13th, 1900—	£	s.	d.
By Rates and Taxes	0	12	0
,, Housekeeper's Salary	20	0	0
,, Curator's Salary	43	6	3
,, Fire Insurance Premium	2	12	9
,, Books, Binding, etc.	27	5	5
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	£127	9	7
,, Balance due to Treasurer, 1899	48	9	4
	£175	18	11
,, Balance due to Treasurer, 1900	18	3	1

PENZANCE, *November 10th*, 1900.

T. R. BOLITHO, *Treasurer.*

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Dr.	£	s.	d.	Cr.	£	s.	d.
November 13th, 1900—				November 7th, 1899—			
R. and S. Garrard and Co.	12	10	0	By Balance	512	10	0
Balance	513	8	9	April 15th, 1900—			
				By Interest to date	13	8	9
	£525	18	9		£525	18	9
				November 13th, 1900—			
				By Balance	513	8	9

LIST OF

PAPERS READ TO THE SOCIETY,

1900.

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1. President's Address. By J. D. Enys, F.G.S.

2. On some Geological Structures in West Cornwall. By J. B. Hill, R.N. (H.M. Geol. Survey).

3. On a Cornu of Cephalaspis Carteri. By A. Smith Woodward, LL.D.

4. Gunwalloe. By Howard Fox, F.G.S.

5. The Sequence of the Lizard Rocks. By Harford J. Lowe.

ON SOME GEOLOGICAL STRUCTURES IN WEST CORNWALL.

By J. B. Hill, Esq., R.N.

(H.M. Geological Survey.)

(Communicated by permission of the Director-General of the Geological Survey.)

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INTRODUCTORY.

In a paper read before this Society two years ago I made a comparison between certain prominent geological features of Cornwall and those of the South of Scotland. As I mentioned on that occasion, the time I had been working on Cornish rocks was too limited for me to speak with any confidence on the geological questions involved. From, however, the study I had been able to make of the coast sections in the Falmouth district I had strong suspicions that the structures were closely related to those met with both in the Highlands and southern uplands of Scotland. The object of this paper is to present to the members of this Society a succinct account of the structural

features of the Palæozoic sediments of West Cornwall, which will be seen to harmonise in a marked degree with what I had already foreshadowed in my previous communication.

Before proceeding further it may be of interest to you to know the general plan adopted for the prosecution of the geological survey of the county. At present we have a staff of three surveyors, one working in East Cornwall and two in West Cornwall.

In the eastern portion of the county my colleague, Mr. W. A. E. Ussher, who has been working for many years on the Devonian rocks of Devonshire, has pushed the survey westward as far as Looe and Liskeard, and has brought the stratigraphy of East Cornwall into continuity with that of Devonshire.

In carrying out the survey of West Cornwall, containing the most important metalliferous district in Britain, it was of vital consequence that the geological structure of the area should be clearly understood; and not until this knowledge was at our disposal should we be prepared to attack the metalliferous districts themselves with any hope of success.

As the interior of the county is covered so largely with decomposed surface rock, it was decided to commence by a detailed examination of the southern coast line between Gerrans Bay and the Helford River, and from this base line to extend the survey along a belt of country

towards the mining districts of Camborne and St. Agnes.

While I have been engaged in pushing the survey towards this mining district from the south coast, my colleague, Mr. S. B. Wilkinson, has been similarly engaged in the west from Penzance as a centre. As the result of our joint work a considerable portion of West Cornwall has been surveyed on the scale of six inches to a mile, and we are now enabled to commence the examination of the mining districts towards which we have been respectively converging.

I will now proceed to lay before you some of the results of my own work in West Cornwall.

As previously stated, the region includes a belt of country running in a north-westerly direction from a base line extending between Gerrans Bay and the Helford River. This district is particularly adapted for detailed investigations on account of the large amount of coast sections which are laid bare. The various estuaries which diverge from Carrick Roads and Helford River penetrate deep into the heart of the country, affording more or less continuous exposures of the strata. Their courses are so tortuous that the examination of their deep indentations has permitted of the beds being continuously traced from the sea coast at Falmouth to practically midway across the breadth of the county. These sea margins have allowed of the detailed examination of over one hundred miles of coast sections.

Another reason for selecting this region to start the survey was the occurrence on this part of the Cornish coast of a well-marked fossiliferous horizon. By commencing the investigations from these strata we had the advantage of beginning from a definite stratigraphical position.

LITHOLOGICAL DIVISIONS.

As a result of the detailed survey of the area, the various slate masses which make up the bulk of the stratified rocks of the district have been separated lithologically into four main divisions, which for convenience of reference will be provisionally referred to by the names of localities where they are typically represented.

The divisions succeed one another from east to west in the following order:—

1. Veryan Beds.
2. Portscatho Slates.
3. Falmouth Slates (variegated).
4. Mylor Series.

Let me point out briefly a few of their distinctive characteristics.

1. *Veryan Beds.*—These consist of blue slates, amongst which occur thin limestones and a well-marked fossiliferous quartzite, as well as a big conglomerate. These beds, after being lost under the sea in Gerrans Bay, reappear on the coast south of the Helford River near the Nare Point.

2. *Portscatho Slates.*—These succeed the Veryan

beds to the westward, and can be traced along the coast line from Gerrans Bay to the St. Anthony peninsula, and their south-westerly extension is met with again in Falmouth Bay opposite. They consist of a series of blue slates, alternating with harder beds, which show every gradation from a sandy slate to a strong grit. The sandy beds are of the same bluish hue as the slates, the colour being largely due to scales of dark mica scattered through them. The presence of so much clastic mica is suggestive of direct derivation from crystalline rocks.

3. *Falmouth Slates.*—These beds bound the Portscatho slates on the westward, and consist of alternations of argillaceous and fine sandy material, in colour varying from green to grey and buff, though occasionally blue argillaceous bands are seen amongst them. The colour, which varies with the character of the sediment, produces the general variegated appearance common to this series. Their mode of decomposition is equally characteristic. The beds become extremely friable, especially those of a sandy nature, are unctuous to the touch and weather into a deep buff colour. On the whole the material is finer than in the Portscatho series, and the strong grit bands which occur in the latter are altogether absent. Occasionally we see a narrow zone of purple and green slates, typically exhibited at St. Mawes Castle, and which forms a valuable aid in the correlation of these beds throughout the district.

4. *Mylor Series.* — This series occurs on the westerly side of the Falmouth slates, from which they can be traced in that direction for many miles. It consists of blue argillaceous and fine quartzose beds very dark in colour. These strata have often a striped or ribbon-like appearance, due to very fine alternations of siliceous and argillaceous material, but in some cases the laminæ are all argillaceous and of varying composition and colour. The bands which are most siliceous weather paler than the purely argillaceous seams. In this series a thin quartzite is seen, but it is rarely more than a foot or so in thickness.

Having now briefly described the sedimentary divisions, we may consider their relationships to one another, the deformation they have undergone as the result of earth stresses, and the effect of these superinduced structures on the general tectonic arrangement of the district.

RELATIONSHIPS OF THE LITHOLOGICAL DIVISIONS.

The occurrence of Lower Silurian strata on the southern coast of Cornwall has been known for many years, by the discoveries of the late Mr. Charles Peach of organic remains, which have been assigned by palæontologists to that period. The region in which these fossils occur was coloured as Lower Silurian by De la Beche in his geological map, and includes the Veryan series of this paper, which contains the fossiliferous quartzite of Carne.

The Veryan series lies in the zone coloured by De la Beche as Lower Silurian, and extends westwards in Gerrans Bay to the boundary of De la Beche's Silurian horizon. The Portscatho series, which is well displayed in the section between Gerrans Bay and the Zoze Point, passes uninterruptedly into the Veryan series without any stratigraphical break. While the appearance within the Veryan series of limestone at Gidley Well, and quartzite at Carne, serve to indicate the apparent incoming of another division of the stratigraphical series, there is no evidence here for drawing a sharp divisional line to mark off two distinct geological formations.

Not only do the Veryan beds pass uninterruptedly into the Portscatho slates, but these latter also graduate imperceptibly into the Falmouth series, which, in their turn, merge insensibly into the Mylor series.

While advantage has been taken of lithological distinctions to separate them into divisions that represented on the map would explain the stratigraphy, it must be distinctly borne in mind that we are dealing with a continuous series of deposits.

But the great mass of the slates in West Cornwall is so uniform in character that unless we are prepared to separate out minor zones having small differences in composition, the true structure of the ground would not be revealed, and we should be unable to determine the general tectonic arrangement.

STRUCTURES.

A detailed study of the coast sections reveals a complex set of structures, which have been brought about as a result of powerful earth stresses. Folds and faults may be detected immediately in any of the divisions, but as the folds are generally isoclinal the plication is not so conspicuous as in a region of normal folding. But the evidence of plication is everywhere so marked that the apparent dip can only be interpreted as the inclination of limbs of folds. The folding has been accompanied by faults which are almost as numerous as the folds to which they bear a direct relation.

The faults often occur every few yards, both parallel to the strike and in oblique directions, with the result that the whole rock mass when seen in ground plan presents the appearance of a huge mosaic. On that part of the south coast with which we are dealing neither large faults nor large folds are common. It would appear that at an early stage of the folding process the resistance to the strains was so feeble that fractures were readily produced. In many districts reversed faults are as numerous as those of normal type.

Although the rocks are everywhere cleaved, we can in most cases on the south coast distinguish between the cleavage and bedding. The alternations from argillaceous to arenaceous material are so numerous that there is little difficulty in distinguishing these structures. The cleavage is

usually oblique to the bedding and varies with the nature of the material it traverses, and is always deflected in crossing from an argillaceous to an arenaceous bed, and *vice versâ*.

The slates on the south coast have a prevailing south-easterly hade, both in bedding and cleavage. By bedding should be understood the alternations which are seen along the various sections, but which in reality are limbs of folds. Where these are regular in their hade, and the cleavage is steady, the section may present such an undisturbed appearance that the folding might easily be overlooked. Where the folding follows the normal type it can be readily detected, but the amount of compression of the strata is often far less than when we are dealing with isoclinal folding, the evidence of which is not so apparent. The obliquity between the cleavage and bedding is not constant. As the cleavage and folding have both been brought about by the same agencies, we see every variation depending on the character and curve of the fold, and the obliquity of the cleavage to the bedding will vary over the different portions of the fold. Although we may often see the cleavage transverse to the bedding, the general tendency has been for the beds to be thrown into a set of isoclinal folds with a definite general hade, and for the cleavage to cross somewhat obliquely at a low angle. The more the folds depart from this general hade, the greater will be the variations between cleavage and bedding.

Besides cleavage the slates are traversed by other structural planes analogous to those found in schistose rocks, and this is especially noticeable where they are made up of alternations of varying material. For not only have these composite beds been more readily acted upon owing to the less uniform resistance they have offered to pressure, but their banded appearance reveals the structures which in slate of more homogeneous material cannot be so readily detected. On examination we often find the rock full of tiny folds and small thrust-planes, with a tendency to a secondary cleavage, while little movement planes appear in the core itself, with accompanying strain-slip cleavage. The cleavage planes pass through the axes of the minute folds, which often culminate in small thrust-planes. The strain-slip cleavage is sometimes as prominent as the dominant cleavage of the beds.

PSEUDO-CONGLOMERATES.

Besides the structures I have enumerated, which are identical with structures in foliated rocks, I will now call your attention to a type of deformation which occupies a more unique position in British Geology.

Over various portions of the area we meet with slate beds enclosing fragments clearly derived from the mass itself, and which at first sight appear to point to contemporaneous erosion. This is most prominent in the Mylor series. The fragments are of material precisely similar to the matrix in

which they lie. They sometimes attain a length of five or six inches, from which they graduate downwards to the size of small pebbles. As a rule the larger fragments are angular, while the smaller are subangular, and may sometimes be seen perfectly rounded. They may consist of either argillaceous or siliceous material. The large number of argillaceous fragments, and the general absence of rounding, could, on the sedimentary hypothesis, be accounted for on the supposition that they had only been transported for a short distance. At first sight I was disposed to accept this interpretation, notwithstanding difficulties which presented themselves here and there. But further study of these structures convinced me that they did not admit of so simple an explanation, and that instead of being due to aqueous deposit they owe their origin to agencies very much more complex, and represent a phase of those processes of deformation to which I have already alluded. In other words, instead of being a phase of the original formation of the rock, it represents a most striking record of its subsequent deformation. Although these structures are confined more or less to particular localities, their extent in the Mylor series may be realised from the fact that these fragmental beds may be followed across the strike for over half a mile, the strata being made up of a mass of fragments from the size of peas up to five or six inches in length, enveloped in a slaty matrix, and with their flat sides lying in more or less parallel planes.

We have already seen that the Mylor series contains beds finely interlaminated in character, which gives the rock a ribbon-like appearance. If we endeavour to trace these laminated beds that are free from fragments into the fragmental or brecciated type, we see that these bands begin to lose their regular appearance, and to be affected by small folds and thrusts, until at last they are nothing more than a mass of segments more or less detached. And it becomes apparent that the fragments which give the brecciated character to the rock owe their origin to small overfolds, which have been isolated by small thrust-faults. Although direct evidence of this origin is not always forthcoming, we occasionally see, step by step, every process in the manufacture, beginning with a regular banded rock, followed by minute folding and small thrust-planes, partially severing the bands, until we see the final stage where these processes have not only succeeded in brecciating the rock, but have culminated in the rolling and rounding of the fragments to such an extent that a pseudo-conglomerate has been produced. The Mylor series, from the changing nature of its interlaminations and the corresponding variation in its limits of compression, appears to have been unable to resist the main stresses without this process of brecciation. Nevertheless, this structure is only of partial occurrence, and is observed mainly in areas of extreme dislocation.

This type of brecciation has sometimes been brought about without folding; instead of fractures

succeeding folding, the stresses have resulted in the direct formation of movement planes, which have isolated the fragments from the main mass.

These pseudo-conglomerates, which are so prominent a feature in the Mylor series, are not confined thereto. They have been observed in the adjoining Falmouth series, especially where the slates assume the fine banded character of the Mylor series. Minor zones of similar material also occur in the Portscatho series, generally when in the neighbourhood of faults. At Rosemullion a pseudo-conglomerate was observed two or three feet in thickness, which I originally took for a boulder bed. It is practically made up of rounded fragments of a hard, sandy material, precisely similar in colour and composition to the matrix in which they are embedded; the fragments sometimes attain a length of three inches. An examination of its structure, however, shows that, like the cases I have already cited, it is a product of mechanical deformation within the rock itself.

In the Veryan series this structure may be also observed. It may be noticed, for instance, in the slate close to its junction with the quartzite in Gerrans Bay. In one of these bands of brecciated slates within the Veryan series a crinoid stem is to be seen, apparently unbroken, unmistakable evidence that the rock, as a whole, may undergo considerable deformation, while portions may escape, probably as a result of the very violence of the processes which have brought about the

phenomena; producing zones of fracture which have relieved the strains on intermediate material.

A brecciated structure of a much coarser type, which severs the continuity of big seams of rock, occurs on the coast section south of the Helford River, but it will be more convenient to defer further consideration of it until I deal with that section later on. It may, however, be stated here that the structure has been produced by similar agencies.

Before concluding my remarks on these pseudo-conglomerates, I would point out that they are undoubtedly related to similar phenomena in the Isle of Man, which have been graphically described by my colleague Mr. G. W. Lamplugh, to whom we are indebted for our earliest exposition of these structures. A reference to his paper[1] shows that "the brecciation has usually taken place along the junction of arenaceous with argillaceous strata, and has chiefly affected the passage beds between such rocks." In Cornwall likewise we have seen that the alternation of materials which compose the strata has been a potent factor in this type of deformation.

STRUCTURES (continued).

Although a study of the sections shows that the slates have been thrown into a set of isoclinal folds, accompanied by faulting, both normal and reversed, yet the most cursory examination reveals

[1] *Q. J. G. S.*, vol. li. p. 587.

an absence of uniformity in their deformation. Zones of contortion are succeeded by others quite free from disturbance. These differences are accentuated where they are divided by faults, which have acted as planes of relief, so that the fault may be bounded by strata highly disturbed on one side, and of regular appearance on the other.

When these faults are of slight hade, and of the nature of thrusts, we may see evenly-bedded strata resting on beds highly disturbed, or *vice versâ*. In the former case, where the thrust planes make little show, we have the semblance of an unconformity, and what might readily be taken for newer beds being deposited on the truncated edges of a more disturbed series. Such an interpretation, however, would be erroneous; these thrust faults are a common feature of all our stratigraphical divisions. As I have pointed out earlier, there is no evidence of a stratigraphical break anywhere except in the conglomerate of the Veryan series. Moreover, identical structures are to be seen in each member of the series, and, as I shall show later, the conglomerate itself at Nare Point has been subjected to the same earth stresses to which the rest of the series owe their deformation.

In this area the folding is so general that the dip must be entirely disregarded. It merely represents the inclination of the limbs of a fold. But whether we are dealing with the hade of these limbs or of cleavage planes, as factors in estimating the thickness of a series, or the general strati-

graphical position of that series as a whole, they are of no value whatever. While we are thus precluded, at the outset, from the assistance of one of the most important elements on which the methods of geological surveying are based, our difficulties will be still greater if we are not prepared to grasp its significance, and to dispense altogether with this method of investigation.

Quartz veins are abundant over the entire succession of strata. Although they are more common in some localities than in others, it would be unsafe to draw conclusions from the noted occurrences that they predominate in any particular series.

Many of them share in the contortions of the district, and transverse cracks may often be observed in them; and, as might be inferred, they are most common in the neighbourhood of the larger faults. They have furnished the greater part of the material for the various shingle beaches that occur along the coast, as well as those of the older raised beaches of the district.

STRATIGRAPHY.

Having described the principal structures which have been superinduced on the slates of this part of West Cornwall, we may now, in the light of this knowledge, attempt the task of unravelling the stratigraphy of the region.

At an earlier stage, on enumerating the lithological divisions into which I had provisionally divided the slate series, I adverted to the fact

that the Veryan series, after being lost under the sea at Gerrans Bay, reappeared on the coast south of the Helford River.

Although these rocks have been correlated by previous observers,[1] the geological sequence of the southern peninsula is of such importance, in connection with so many unsolved problems of Cornish geology, that I made a special study of the coast sections between Falmouth Bay and the Nare Point, in order to determine the relations between the various rock masses that are exposed. The following notes on this section are extracted from my official report for last year:—

From Maen Porth the coast, as far as the Helford River, presents an uninterrupted section of the blue slates and fine sandy beds of the Portscatho slate series in their normal condition. South of the Helford River they are well exposed as far as St. Anthony Creek. As they are followed southward, however, they have suffered more severely from the stresses which have induced the folding and cleavage of the rocks. At Dennis Head the structures set up by these movements have been carried a step further. The strata have been, as it were, subjected to mylonisation (or crushing) of a coarse type, insomuch that they have been reduced to a mass of coarse lenticular patches of rock, the lenticles being several feet, in some cases

[1] Mr. J. H. Collins, who has contributed largely to our knowledge of Cornish geology, long ago insisted on this correlation.

yards, across, and the whole presenting the character of a regional breccia. These lenticles, when they have been torn from quartzose beds, resemble huge boulders; in other places the apex of a folded limb has been detached and isolated from the parent mass. This extremely coarse type of brecciated structure is more or less continuous along the coast as far as Porthalla, where the northern edge of the Lizard "complex" appears.

Between Dennis Head and the Nare Point a conglomerate is interbedded with blue slates. Near the Nare Head a quartzite appears, and further south, nearer Porthalla, a small limestone band. The limestone and quartzite, as well as the conglomerate, are found associated with the blue slates.

The conglomerate was described by De la Beche,[1] who recognised in it fragments of hornblende-slate, in addition to the material supplied from local sources. It is well seen on the shore east of Men-aver Point, where it has an outcrop of nearly a third of a mile. Still farther east, at the Nare Point, conglomerate is again exposed for a few yards. As the strata are highly folded, it is probable that the successive outcrops are parts of the same mass. Before the main body of the conglomerate comes on, thin seams of fine conglomerate may be observed to be intercalated in the slates. These seams vary from six inches to a foot in thickness. Commencing next the slates

[1] *Report on the Geology of Devon and Cornwall*, 1839, p. 94.

as sandstone they rapidly become coarser, occasionally including fragments three or four inches across. The fragments are made up of black slate and greyish-green slate, rounded and subangular, together with angular pieces of white quartz. This part of the rock is generally fine-grained. The coarse conglomerate begins with a fringe of similar material, which also forms the matrix of the coarse mass. The larger boulders are made up of slate, quartzite, and vein-quartz. Many of the quartzite blocks are of huge size; the smaller boulders of this material are generally well rounded, as are also many of the fragments of white quartz. In addition to these fragments, which have been derived from rocks in the immediate neighbourhood, boulders of foreign material are also present, consisting of granitic and felsitic rocks, some of which are foliated; quartz-felsite and green schistose fragments, some of which contain hornblende, and are possibly referable to the hornblende schists of the Porthalla district to the southward, while granitic and felsitic fragments may have been derived from the older rocks of the Lizard; at least they do not resemble the granite and associated rocks that lie to the north of this part of Cornwall. These far-derived materials are generally in a highly decomposed condition; they have also suffered brecciation from the stresses to which the conglomerate has been subjected in common with the rest of the rocks of the district. Amongst the fragments of green rocks in the conglomerate, one which was very serpent-

inous but highly fissile unfortunately could not be extracted from the rock. Whether it should be associated with the Lizard serpentines must remain doubtful. Boase, indeed, has stated that fragments of serpentine and daillage-rock occur. De la Beche observed hornblende-slate, but could not detect serpentine or daillage-rock. Since the time of De la Beche's survey the existence even of pieces of the hornblende-slate has been doubted. My observations tend to confirm De la Beche's statement.[1] If the fragments of foliated granite have, as is probable, been derived from the Lizard district, serpentine may perhaps yet be found included in it. It must be borne in mind, however, that the granite and other igneous fragments supposed to have been derived from that district are generally much decomposed, so that the chances of so soft a rock as serpentine surviving attrition during transport might not be great. Although better able to resist severe movements of the terrestrial crust than the slaty rocks among which it lies, the conglomerate has undoubtedly experienced similar stresses. Its upper layers have yielded to the movements as completely as the slates on either side of it. Moreover it is traversed by planes along which shearing

[1] Professor T. G. Bonney has informed me that he had found a specimen of similar material, but rather decomposed. In respect to my own specimens, while they are sufficiently fresh to leave very little doubt as to their igneous character, my own knowledge of the Lizard district is too limited for me to offer an opinion whether these greenstone fragments can be referred to that area or to other localities where greenstone is known to occur.

has taken place, so that its constituent boulders have sometimes been broken across. Thin quartz veins occasionally traverse both boulders and matrix. The quartzite boulders are sometimes almost welded into the gritty parts of the conglomerate. A mica-trap dyke rises in the conglomerate, in which it is no doubt intrusive, although its junctions with that rock are not seen. No fragments of it occur in the conglomerate. The mica-trap is of the normal type of the dykes which in this district cut the Portscatho slates.

The quartzite is first seen on the south side of Nare Point, but on account of the coarse brecciated structure that has been previously described as occurring in this neighbourhood, it cannot be continuously followed. It occurs here as a lenticle about 10 feet long and 5 or 6 feet wide. A little further south, between Nare Point and Nare Head, the quartzite seen a little inland above the cliff probably represents the parent mass from which this large lenticle has been isolated. It is a grey compact rock which has suffered a great deal from the brecciation of the district. Its interstices are filled with vein-quartz, consequently it is a mixture of quartzite and secondary quartz. Except that it is more brecciated, it is similar in character to the quartzite of Carne in Gerrans Bay. The thin limestone seen near Porthalla also resembles the limestone at Gidley Well in Gerrans Bay.

Besides the quartzite of Carne and the limestone

of Gidley Well, the Veryan series of the Gerrans Bay district also contains a conglomerate, and is thus brought still further into relation with the strata between Dennis Head and Nare Point south of the Helford River. Indeed, the evidence furnished by a study of the two sections is ample for the correlation of the rocks in the two areas. De la Beche clearly recognised the probability of their identity,[1] although the Veryan beds were coloured on his map as Lower Silurian, while what must be regarded as their equivalents south of the Helford River were coloured as Devonian. As the Veryan beds have been determined by palæontological evidence to be Lower Silurian, it is clear that strata of Lower Silurian age extend still further to the south-west, and that they form the northern boundary of the Lizard complex.

While earth stresses have so deformed the rocks as to interfere with the continuity of individual seams as in this quartzite, the same causes have in other cases produced quite an opposite effect; for instance, the quartzite at Carne, which on the sea coast is only a few feet thick, has been so intensely folded that it occupies a considerable area on the hillside above, and presents the appearance of a bed of considerable thickness. In this case the quartzite has been folded, and the folds so packed together that a narrow bed has been made to occupy a considerable outcrop, while on the

[1] *Op. cit.*, p. 95.

other hand the quartzite of Nare Point has been so squeezed and dislocated that it is only represented by a series of lenticles. A small quartzite band that occurs in the Mylor series has a similar behaviour. On the coast between Restronguet Point and Porthgwidden a seam of quartzite one or two feet thick is represented by a series of lenticles among the folded and brecciated slates in which it occurs.

The Veryan series is succeeded further west by the Portscatho series, which is well exposed along the section from Gerrans Bay to the Zoze Point, and on the eastern side of Carrick Roads more or less continuous sections of this series are met with in the estuaries between the Carrick Roads and Truro, including the estuaries of the Fal and the estuary that penetrates as far as Tresilian. On the west side of the Carrick Roads they are seen extending from Falmouth Bay to St. Anthony Creek south of the Helford River, and follow a south-westerly course until they again reach the coast, where they are typically seen at Gunwalloe.

The Mylor series occupies an equally broad tract of country on the western side of a line drawn approximately north and south between Falmouth and Truro.

The Falmouth slates which lie between the Portscatho slates and the Mylor series have been ascertained by the mapping, as far as this district is concerned, to be of much smaller extent than the

two divisions which it divides. They cannot, for this reason, be so continuously traced.

Between Falmouth and Truro they appear in lenticular strips, either as infolds within the Portscatho series or else as partitions between the Portscatho and Mylor series, while occasionally they may be seen as infolds within the area of the Mylor series. The axes of the isoclinal folds, into which all the groups of strata have been thrown, do not correspond with the general strike of the stratigraphical zones, but cross it rather obliquely, so that the mapping brings out several more or less parallel lenticular masses of the Falmouth series along a zone oblique to their longer axes, the several repetitions being due to isoclinal folds. The ground southwards from Falmouth affords similar evidence. The large belts at Falmouth and Maen Porth apparently "nose out," and the section along the Helford River which crosses the strike shows numerous zones of this series interfolded with the Portscatho slates. So close are these intercalations that in many cases it is quite impossible to separate the stratigraphical divisions on the map.

The variegated slates of Falmouth are more arenaceous than the series at St. Mawes, and as these are carried still farther to the south-west, they are found to be mainly arenaceous, almost to the total exclusion of argillaceous material, so that at Helford River they are represented almost entirely by buff sandy beds. Hence the alterna-

tions in colour from the green argillaceous to the buff sandy type are also lost, and consequently, instead of being variegated, they are here of a uniform buff tint. Within this series of strata, both at Falmouth and at St. Mawes, narrow zones of sharply-contrasted purple and green slates have been observed, likewise to the north of St. Mawes, between Mesack Point and Turnaware Point, where rocks of this character are strongly developed in the variegated series.

From the foregoing descriptions of the stratigraphical divisions, after making due allowance for repetition by folding, we observe, nevertheless, a general order of succession, commencing with the Veryan series on the extreme east, followed by the Portscatho slates, which in their turn are succeeded by the Falmouth beds, and finally by the Mylor series, which forms the most westerly group. If we proceed to follow the course of these beds beyond this region, which has been definitely mapped, we find a confirmation of this order of succession. Take, for instance, the section between Gunwalloe and Penzance. As I have noticed before, the Portscatho series is well represented at Gunwalloe, and similar beds may be met with until about half a mile south-east of Looe Pool, when the Falmouth beds make their appearance, until midway between Looe Pool and Porthleven they are replaced by the Mylor series, which occupy the rest of the section until they are cut off by the big granite mass to the west of Penzance.

Similarly, if we follow the beds to the westward from the railway between Perranwell and Truro, we meet with a repetition of the Mylor series and the Falmouth series. These divisions may both be seen along the north coast between Perran Porth and Portreath.

Leaving out of consideration the rocks which make up the Lizard complex, there are strong reasons for concluding that the four sedimentary series I have described make up the whole of the Palæozoic sediments of West Cornwall.

In attempting to assign a geological age to the members of the series here described, we are confronted with the difficulty that only one member of the series has yielded organic remains of sufficient chronological value. Fortunately for our purpose the Veryan series contains fossils, originally discovered by the late Mr. Charles Peach, and determined by competent palæontologists to be of Lower Silurian age. This determination has been confirmed during the present year by an eminent Continental geologist, Dr. Barrois, of Lille, after an inspection of the specimens in the Museum of this Society.

The Nare Point conglomerate contains boulders and pebbles of quartzite, and not improbably marks a break between the Upper and Lower Silurian formations. As the Portscatho, Falmouth, and Mylor series appear to occupy an intermediate position between Lower Silurian and Devonian horizons, we may infer from the scant evidence at

our disposal that these series may be Upper Silurian. If this hypothesis should prove to be correct, the Devonian system is not represented in this part of Cornwall. Their accurate determination, however, must await the detailed survey of the intervening region which separates them from definite Devonian horizons.

CONCLUSIONS.

In conclusion let me epitomise briefly the main points in connection with these rock structures.

The structures of the stratified formations in West Cornwall are identical with the structures of crystalline schists. In the Falmouth district, so far as yet examined, true slates have not been met with. The strata have been thrown into a series of isoclinal folds, accompanied by small faults. With these folds and faults minor structures have been set up until the whole rock has often become a mass of minute folds and thrusts, with their accompanying strain-slip cleavages. These processes, as we have seen, have been carried so far that "crush-conglomerates" have been produced on a large scale. It is evident, from a study of this district, that had the rocks been subjected to these stresses at a greater depth and below the zone of fracture, where they would not have been so free to move, they would have been converted into true schists. They possess now every structure of schists, but the mineralisation has been wanting.

The visible dip of the rocks is of no value, except as registering the inclination of the limbs of folds. As an illustration of this fact, it may be pointed out that although the strata have a general dip to the south-east between Falmouth and Truro, and we are apparently crossing the strike from the coast to the heart of the county, yet instead of getting deeper in the stratigraphical series we are on precisely the same geological horizon at Truro as at Falmouth, the intervening ground being made up of a succession of isoclinal folds.

ON A CORNU OF CEPHALASPIS CARTERI FROM THE LOWER DEVONIAN OF LOOE.

By A. Smith Woodward, LL.D.

Many years have elapsed since the first recognition of fragments of Cephalaspidian fishes in the Lower Devonian rocks of Cornwall,[1] but no remains sufficiently well preserved for generic and specific determination have hitherto been discovered. The most satisfactory specimen at present known seems to be the cornu of a head-shield, which has recently been submitted to me by Mr. J. H. Collins, and is worthy of a brief note. It was found this year by Mr. Upfield Green near the Old Mill at Looe, and is now in the Penzance Museum (specimen No. 1,718).

This fossil measures 0·027 m. in length by 0·006 m. in width at its widest end. It tapers gradually, and both its borders are nearly straight, so that there is no approach to a sickle-like form. The pointed end is broken away; and both this

[1] E. Ray Lankester, "On the Discovery of the Remains of Cephalaspidian Fishes in Devonshire and Cornwall," *Quart. Journ. Geol. Soc.*, vol. xxiv. (1868), pp. 546, 547.

fracture and another above it prove that the specimen has a small central cavity. The flattened face of the cornu may be either superior or inferior: it is completely covered with a close ornament of very fine tubercles, which are slightly elongated and arranged in series nearly coincident with its long axis. The outer margin bears a regular series of about sixteen large, broad tubercles, with their acute apices inclined backwards; they are separated by interspaces scarcely exceeding the length of their respective base-lines. The inner margin exhibits a few larger hook-shaped tubercles, with the apices curved forwards. No other fragments of the fossil occur on the same piece of rock; it is merely associated with remains of the common *Pteraspis cornubica.*

The long and slender proportions of the cornu now described, and the presence of large denticles on its outer margin, are at first sight suggestive of *Eukeraspis;* but the Cornish species is excluded from this genus by the presence of the inner hooklets. It is similarly distinguished from *Auchenaspis*, which has a tuberculated rim. There is, however, no reason why it should not be referred to the genus *Cephalaspis*, in which it will form the second known species provided with large marginal tubercles. The only species thus characterised hitherto discovered seems to be *C. Pagei*, from the Lower Old Red Sandstone of Forfarshire.[1]

[1] E. Ray Lankester, "Fishes of the Old Red Sandstone," part 1 (*Pal. Soc.*, 1870), p. 49, pl. x. figs. 3, 4, pl. xi. fig. 4. Including

Its cornu is readily distinguished from the Cornish fossil by being much shorter and broader and more nearly sickle-shaped. The species from Looe is therefore either unknown or to be identified with the so-called *Cephalaspis* (?) *Carteri* from Lantivet Bay.[1] For the present it seems best to assume its identity with the latter, which exhibits a similar fine tubercular ornament.

Cephalaspis asper, Lankester, *ibid.*, p. 50, pl. x. fig. 5 (A. Smith Woodward, *Catalogue of Fossil Fishes in the British Museum*, part ii., 1891, p. 183).

[1] E. Ray Lankester, *op. cit.*, 1870, p. 42. *Steganodictyum Carteri*, F. McCoy, *Brit. Palæoz. Foss.* (1855), pl. iiA., fig. 4.

GUNWALLOE.

By Howard Fox, F.G.S.

(Read November 13th, 1900.)

The district of Gunwalloe has long received well-deserved notice at the hands of those familiar with its Antiquities, History, Geology, and Botany.

The Rev. A. H. Cummings, formerly Vicar of Cury and Gunwalloe, published a volume[1] full of interest, in which he dealt with its churches, its history, and its legends in so complete and able a manner as to leave little for successors to add.

The Rev. C. A. Johns, in his *Week at the Lizard*, published over fifty years ago, gave a list of the rarer plants and their habitats at that date; and Mr. F. H. Davey, of Ponsanooth, is about to publish a new list, which will give the botany of the district as at present existing. Miss Beatrice Foster, of Trevillis, added one plant to the flora by finding *Orobanche elatior* (Tall Broomrape) last summer, parasitic on the roots of *Eryngium maritimum* (Sea Holly), in the sand of Gunwalloe Beach.

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[1] *Churches and Antiquities of Cury and Gunwalloe.*

The geology of these parishes was noticed very early in the history of your Society. In your first volume of *Transactions*, published in 1818, Mr. Ashurst Majendie, one of your founders, in a "Sketch of the Geology of the Lizard District," refers on page 33 to the fine sections of "singularly contorted strata" of "Greywacke slate" near Gunwalloe Cove.

In the succeeding year Professor Adam Sedgwick devoted much time and attention to the minute examination of the same district, and two years afterwards read to the Cambridge Philosophical Society a very full and accurate description of the chief features of this complicated and interesting coast, in a paper entitled "On the Physical Structure of the Lizard District."[1]

He wrote as follows: "In a cove about a quarter of a mile north of Gunwalloe Church the beds in the lower part of the cliff are twisted into a system of Gothic arches, and the upper portions exhibit a similar curvature in an inverted position, so that the lancet-shaped masses from above are supported in the interval between the lower system of arches. We do not recollect to have ever seen a curvature more difficult to account for by the ordinary action of mere mechanical forces." He further writes: "There can be no doubt but that the slate between Loe Bar and Bollerium[2] is coeval and continuous

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[1] *Trans. Cam. Phil. Soc.*, 1821, p. 37.

[2] Polurrian of modern maps.

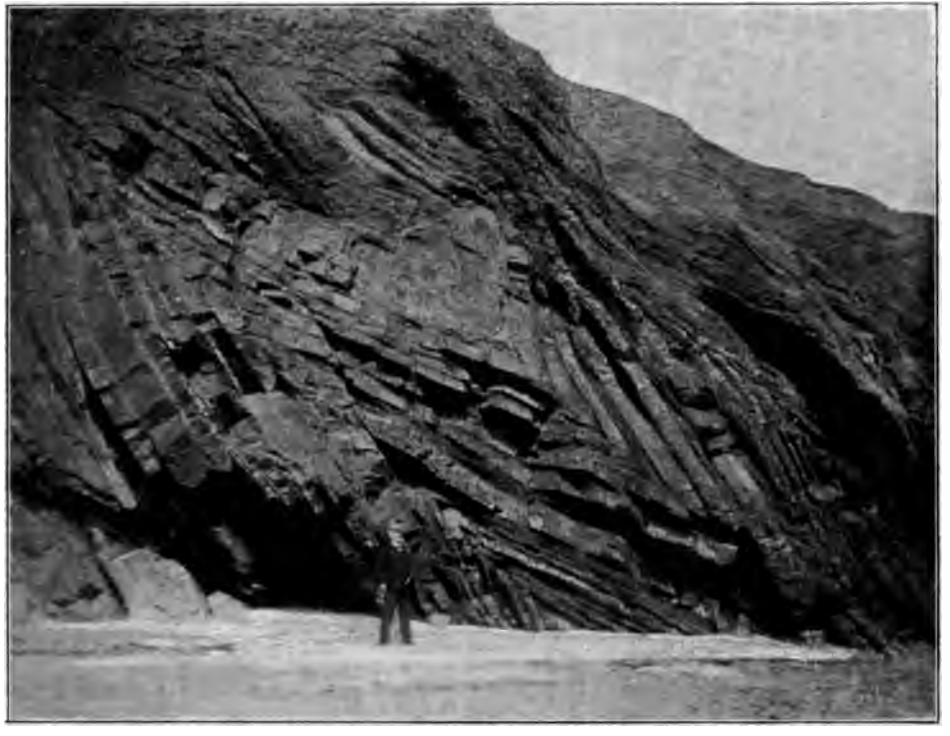
with the formation which stretches from the Helford River to Porthalla."

This "system of arches" of Professor Sedgwick's is well seen in the enlarged photograph now presented to your Museum, and also in the annexed reproduction of one taken last June. The thick pale bands are grits, the thin dark bands are much-squeezed shales, and there are numerous quartz and calcite veins. A confirmation of the Professor's conclusion that these rocks are coeval and continuous with the rocks between Porthalla and Helford has been recently supplied by the discovery of radiolarian cherts of the same type, both at Chypons, Mullion,[1] and north of Porthalla.[2]

This same series of banded grits and shales, which are folded so conspicuously north of Gunwalloe Church in the cliffs of a stretch of cove, enjoying the quaint name in the parish maps of Jangye-ryn, can be traced at intervals as we follow the coast to Loe Bar, at the south end of which they are conspicuous.

The shales associated with these grits throughout the extent of their exposures give occasional indications of organisms, most of which suggest plant remains. They were described in a paper[3] in your last year's *Transactions*, as also was an undoubted fossil found in the shale above high-water mark in the rocks south of Loe Bar, adjoining Gunwal-

[1] *Trans. R. Geol. Soc. Corn.*, vol. xii. part 4, 1899.
[2] *Ibid.*, vol. xii. part 1, p. 43, 1896.
[3] *Ibid.*, vol. xii. part 5, 1900, p. 357.



CONTORTED BEDS AT JANGYE-RYN, GUNWALLOE.

To face page 436.

PLATE 17

NEMATOPHYCUS HICKSII.

To face page 437.

loe Fishing Cove. Mr. Rupert Vallentin kindly sketched this fossil, as reproduced in the annexed plate (No. 17). As mentioned in the above paper, Mr. E. T. Newton, F.R.S., thinks it is a plant. It recalls to him the forms described under the genus *Nematophycus* (Carruthers) as an Alga.[1]

Notwithstanding repeated examinations of this coast during the past year, no organism with more definite structure has hitherto been found.

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[1] See *Q. J. G. S.*, vol. xxxvii., 1881, p. 490.

THE SEQUENCE OF THE LIZARD ROCKS.

By Harford J. Lowe.

The crystalline rocks of the Lizard peninsula form a rare and fruitful field for the student of igneous and metamorphic rocks. Their complex arrangement and peculiarities have put to the test the skill, experience, and judgment of our most noted geologists and petrologists, while their intricacies and varieties have given rise to several hypotheses intended to account for the unusual phenomena to be observed among them. A very considerable mass of literature dealing with the different phases of the geology of this series is to be found in the various scientific journals and Society Transactions, and it is probable much more will be added before any full and accurate handbook will be compiled that will correlate the recorded facts, account for the apparent anomalies, reconcile the seeming discrepancies, and weave the whole into a rational history of the movements and natural processes that have taken place in the earth's crust within this small area.

I am deeply indebted to that excellent observer

and enthusiastic geologist, Mr. A. Somervail, Honorary Secretary to the Torquay Natural History Society, not only for reviving an old interest in geological study by his inspiring enthusiasm in a favourite pursuit; not only for much help in the field among igneous rocks; but particularly for his glowing accounts of the interest and beauties of the Lizard that engendered the desire to seek similar experiences by visiting the spot and revelling in its charms, novelties, and problems.

My first visit was purposely made without much literary preparation, having read over only two or three of the earliest papers on the subject, my intention being to test my observations and judgment with that of the more skilled and experienced. During a fortnight's hard pleasure, full of surprises, I traversed nearly the whole coast line from Polurrian to Porthallow, closely observing all available sections, and thus gaining a general idea of the various kinds of rocks, and something of their relation to each other. In this visit I was fortunate enough to find a mineral in crystalline form (Natrolite), not hitherto recognised in the district, specimens of which the Royal Geological Society of Cornwall accepted for their Museum. Since then, through the kindly assistance of Mr. Howard Fox, I have been able to study nearly the whole of the literature bearing upon the geology of that district, and have supplemented my knowledge by other visits of considerable duration.

One reason for the second and subsequent visits was to examine points referred to in papers written by Professor Bonney and Major-General McMahon respecting the relation of the Granulitic series to the other rocks. My observations in regard to this very peculiar rock led me to account for its dual composition by supposing a simultaneous upflow of two magmas, one acidic, the other basic. These, owing to their consistency, did not intimately mix, as they were rolled together during their passage along the vents of eruption, or rather channels of intrusion, but were ultimately pressed into the folds now seen, giving the rock its strikingly banded character.

To present the idea a little more definitely. Suppose a viscous basic magma on its upward course to be met by another flow of a more liquid acidic material entering the same channel. The two magmas flowing onward together would in consequence be rolled and folded over and into each other, their consistencies being unfavourable for intermingling of components except to a small extent at planes of contact. The folds thus formed by simultaneous flow would become flattened and attenuated by pressure during intrusion, and ultimately assume the appearance of light and dark layers of irregular thickness cooling and crystallising into a banded rock of dual composition.

The possibility of such an occurrence was suggested by a paper read before the Torquay Natural History Society by Mr. A. R. Hunt upon the "Origin

of Granite." I was unaware until some time after the idea had been formulated in my mind that Messrs. Bonney and McMahon had years before, in their joint paper,[1] propounded a theory to explain the same phenomenon, which my own conjecture in many respects resembles. In that valuable and comprehensive memoir just referred to the authors conclude that this foliated rock, named by Professor Bonney "Granulitic," follows in chronological order the Hornblende Schist, thus relegating the extrusion of the Serpentine, Diorite, Gabbro, and Greenstones to times subsequent to the formation of the banded rock. The observations during my first visit led me to think the Granulitic must be one of the later rocks, if not indeed the last addition to the complex, and it was mainly with the intention of correcting my impressions in accordance with the authoritative opinions therein expressed that I made a second visit. But, to my surprise, I could not find the evidence referred to in a general way by these eminent collaborators; while that indicated more explicitly, that was met with, did not give clear and indisputable testimony in the direction expected, but appeared liable to an interpretation opposed to that given. Moreover, I thought I saw numerous other instances that supported my first impression, as well as additional evidence of another kind. A third visit and more careful examination forces me to conclude there is a possibility, that in this

[1] *Quart. Journ. Geol. Soc.*, vol. xlvii., 1891.

particular, an error in inference may have arisen from insufficient data. I am aware it will appear presumptuous on my part to attempt to controvert a conclusion arrived at by men of such eminence in the world of scientific observation and deduction; but I plead a careful examination with unbiassed mind, the common desire to resist possible error and proclaim truth, as well as the stimulus of perhaps being able to add one item to the great book of science. Besides, the reputation of these noted geologists is a guarantee that they would welcome any new fact or additional evidence towards establishing true inferences, and would treat with due consideration any observations made honestly by unknown workers in their field of research. Of this I am more assured by noting in their paper that they seem themselves hardly satisfied with the evidence from which they drew this particular conclusion, and acknowledge appearances seemingly contradictory to it. They say :—

"We do not deny that occasional sections may be found in which the present relations of the two are the result of faulting, or which did they stand alone might seem to support the view that the Granulitic rock was intrusive in the Serpentine, but after again examining all the sections on both coasts described by Professor Bonney in 1877, we have not the slightest doubt that the Serpentine is intrusive in the Granulitic rock, which was at that time substantially in its present condition, and

that as a rule their relations have not been disturbed to any noteworthy extent."[1]

It may be that since this was written some sections have been obscured and others laid open, and if so it would appear that the few instances in favour of the view have become less evident, while new exposures point to a different conclusion.

I have not been able to find any case of truncated or "ragged" edges of the bands in the Granulitic except where there is an unmistakable fault, and I have met with only one indisputable instance of an isolated mass of the Granulitic, viz. at Enys Head, which appeared to have been faulted down and left by denudation exposed on the Serpentine. Instead of meeting with broken or discontinuous folia where the Granulitic is in contact with the Serpentine, my attention was arrested by the persistence of the banding in almost every instance. The alternate bands of acidic and basic material are invariably intact and in conformity with the shape of the mass of Serpentine they adjoin, wrapping over and under it, accommodating themselves to the included mass by thickening or thinning out, sending loops into or sweeping round the Serpentine, and altogether adapting themselves to the varying forms of an intruder. Between the Balk and Kennack Sands scores of sections are to be met with showing the junction between the Granulitic and Serpentine,

[1] *Q. J. G. S.*, vol. xlvii., 1891, p. 468.

and perhaps the most remarkable feature common to each case is that the Serpentine is surrounded, or indeed enveloped by a greenish-grey fibrous mineral, varying in thickness from half an inch to 2½ inches; indeed in some instances the whole mass of Serpentine, when small, has been converted into that fibrous mineral. Occasionally it occurs in a more decidedly crystalline condition, is always soft and unctuous, suggesting a form of steatite to which no doubt it is closely allied.

It is referred to by Messrs. Bonney and McMahon in these words: "The Serpentine at the margins is often decomposed, and its structure is obscured by secondary chrysotile, steatite, and other like minerals." Now wherever a zone of contact between the Granulitic and Serpentine is met with this mineral intervenes in a remarkably uniform manner; but no such phenomenon is to be seen in the instances of the contact between the Hornblende Schist and the Serpentine. The mineral is an alteration product derived from the Serpentine, and if the Serpentine is intrusive in both rocks alike, all having been since subjected to the same conditions, why should the Serpentine in the Granulitic have undergone changes it has been free from in the Hornblende Schist? In most cases the fibres of this alteration mineral lie over the Serpentine mass like a covering of felt, but sometimes where the mineral is thicker the inner fibres are vertical to the perimeter of the mass, while the outer elongations lie in a uniform

direction at an obtuse angle to the vertical parts as though bent over by pressure and sliding movement of the contact matter.

The following illustration is taken from an instance to be met with near the gate opening upon Kennack Sands. The Serpentine is a mass several feet long by one to about two feet wide, embedded in the Granulitic, which takes the form of an arch, with the south end buried in the sand, as though bending under the Serpentine cliff. The section itself is sometimes buried in sand. In this

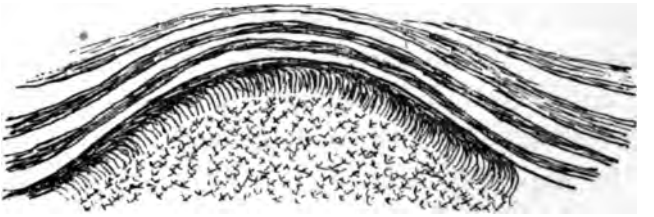

FIG. 1. KENNACK.

and the other illustrations there will be no difficulty in distinguishing the banded rock from the Serpentine, represented by irregular crosses.

In attempting to account for the presence of this mineral in the Granulitic, and its absence in the same form and similar positions in the Hornblende Schist, I am led to consider the possibility of the molten magma, from which the Serpentine was formed, having come into direct contact with the Hornblende Schist in such a mobile and heated condition as to form the welded junctions spoken of by Messrs. Bonney and McMahon in their joint

paper, which magma having crystallised into the Peridotite rock had been partially or wholly metamorphosed into Serpentine before the invasion of the Granulitic matter. This Granulitic magma meeting with and enclosing portions of the secondary product, Serpentine, would subject it to additional heat and pressure, which might further alter it into the enveloping mineral at the contact planes. This difference in contact is noticed by the authors of the paper before referred to. The welding is instanced in the case of the Serpentine and Hornblende Schist, and the fact of the Serpentine not even adhering to the Granulitic mass mentioned. The latter is thus explained: "Signs of crushing and slickensides may no doubt not unfrequently be seen at junctions. This is only to be expected, because the tenacity of the two rocks is so different that even if welded they would have parted under strains from ordinary earth movements." An obvious comment to this is that the Dioritic portion of the Granulitic being almost identically the same in composition as the Hornblende Schist, in the quality of tenacity they would be also much alike. Why then should there not be welding in both cases? and why should the earth movements, both have alike been subjected to, bring about such opposite results?

I was first impressed with the idea that the Granulitic must have been intruded into the Serpentine by the instance shown in the following figure:—

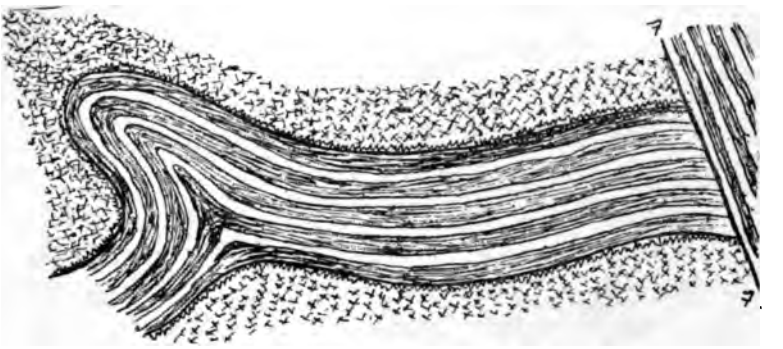

FIG. 2. PARN VOOZE.

The section is to be met with at the south end of Parn Vooze, near the foot of the path cut down to the Cove. The interpretation which occurred to me was that a tongue of the Granulitic magma, while making its way through the Serpentine, had met with sufficient resistance to be deflected and form the bend shown in the diagram. In this tongue the basic matter is in much greater proportion than the acidic. Following are representations of half a dozen more contact sections, out of the many available, which will sufficiently demonstrate the points for consideration. In respect to them I may say that although in part they are diagrammatic, yet in their main lines they are copied from nature, and in most cases the outlines of the Granulitic bands in contact with the Serpentine sufficiently simulate the originals to serve the purpose of demonstrating the points referred to.

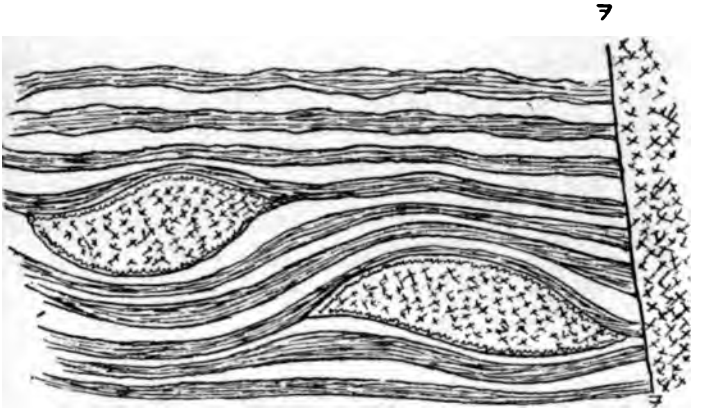

FIG. 3. CAERLEON COVE.

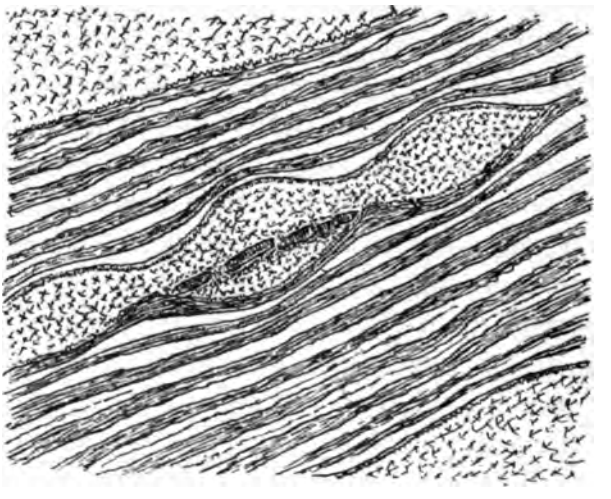

FIG. 4. KILDOWN HEAD "FLAGSTAFF" QUARRY.

FIG. 5. BELOW KILDOWN HEAD QUARRY.

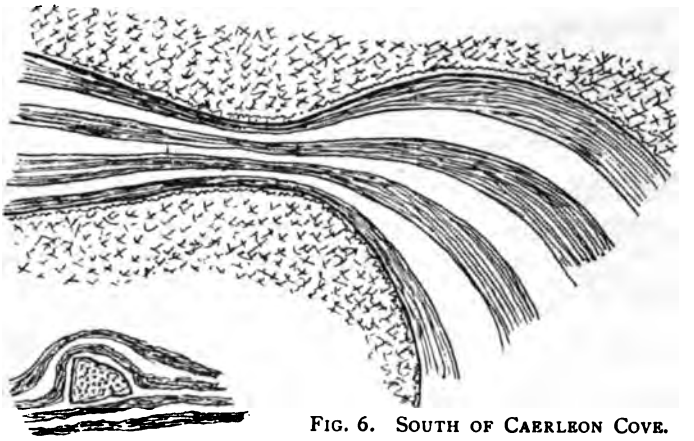

FIG. 6. SOUTH OF CAERLEON COVE.

FIG. 7. POLBARROW.

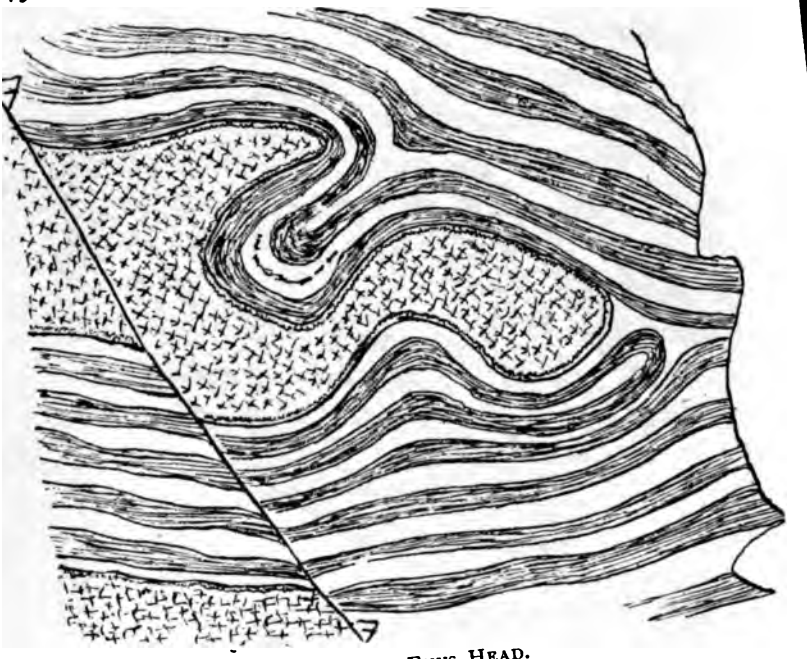

FIG. 8. ENYS HEAD.

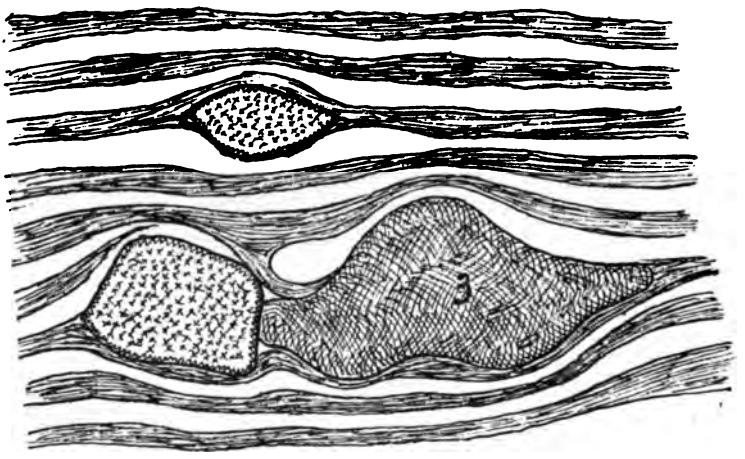

FIG. 9. KILDOWN COVE.

Considering the sections in a general way it is difficult to conceive how the masses of Serpentine, varying in diameter from a few inches to as many yards, could force their way into so unyielding a rock as the Granulitic without fracturing the bands and sending some of its molten matter in directions transverse to the lines of foliation, and yet in no single instance is this seen. But not only must the hypothesis of the intrusion of the Serpentine explain the reason of the magma invariably making its way between the folia of a consolidated igneous rock without rupturing either basic or even more brittle acidic bands, while forcing them sometimes several feet asunder, but it is required to show how these beds of solid rock could be stretched and thinned out in many instances, or occasionally shortened and thickened in order to suit the conditions of interference. It must also maintain that an intruding magma may draw out loops from the folia of an extremely tough rock and bury them in its substance, the foliation still remaining intact. (*Vide* Figs. 5 and 8.) I have two pieces of bent rock of about a finger thickness, taken from small masses of Serpentine in the Granulitic, which show the folds distinctly. Moreover, it is necessary the theory should also explain how in a solid rock these disturbances should be so limited in their effects, the foliation very near to the supposed intrusion remaining in its normal condition.

Fig. 7 represents a section of Serpentine of less than a foot in diameter with the folds of the

Granulitic wrapping round it in such a manner as to compel one to conclude it must have been a solid body enveloped by a plastic material, and not a fluid mass forced into a solid foliated rock. If we assume that the Granulitic in a viscous condition invaded the Serpentine, all the phenomena represented in the illustrations are simply accounted for. The masses of Serpentine broken off and taken up by it as it forced its way through would become enveloped in the folds of the plastic material, which would fit closely to the mass, following every irregularity that was not obliterated by the moulding action of heat and pressure. This most obvious way of accounting for the continuous banding also carries with it a simple explanation of the variation in thickness of the bands in contact with and near to the included mass. The resistance offered by the solid Serpentine mass to the forces operating upon it from the surrounding magma would assume the form of a reacting force on the plastic matter, causing a flow along the bands from the points of greatest resistance to those of less, thereby bringing about a thickening and thinning of the bands until the pressure upon the mass became uniform.

Figs. 3, 4, and 9 show this result; and as it appears the acidic part of the magma adapted itself more readily to this pressure than the basic, it may be inferred that the lighter coloured material was in a more liquid state than the darker or basic during the simultaneous flow. Other considerations

in connection with this rock also point to the same conclusion.

Fig. 4 shows a peculiarity which I think has been pointed out as an instance of the Granulitic included in the Serpentine. It appears as though a band of the basic material had been longitudinally divided, one portion folding round the mass, the other passing through the Serpentine and apparently slicing a piece off. The part within the Serpentine is broken across in several places and a little dislocated, but as the Serpentine material does not connectively occupy the fractures it seems most probable they are owing to movements subsequent to the original arrangement. The possibility of such a penetration taking place may, I think, be admitted when we consider the jointed character of the Serpentine in connection with the rigidity a thin layer of a viscous material might assume, under the influence of three forces acting one at right angles to the other two opposing each other, as would be the case in a sheet of lava being driven through rock at a considerable depth.

In Fig. 9 one of the included pieces is intentionally shaded differently from the rest. This section is particularly interesting in presenting three masses of Serpentine within an area of about six feet by four. Two of these small masses present sections of bastite-spangled Serpentine with the usual fibrous border of alteration product, but the other mass distinguished by Fig. 3 is

shaded differently, in order to indicate that the fibrous envelope in this instance covers it entirely, and represents the termination of a mass of Serpentine not denuded of its outer covering. This evidently cannot be the section of a lava-flow, but is unmistakably the end of a mass of comparatively recent exposure. As though to complete this piece of evidence, there lies near to it a small hollow of a basin shape and size, which contained, when found, a small quantity of Serpentine adhering to its deepest part. This shelled out entirely with a stroke or two of the hammer, leaving a clean and smooth cavity marking the impress the small included mass had made upon the enveloping Granulitic magma.

Coming now to evidence of a somewhat different character, I give representations of two sections which appear to unequivocally declare the intrusion of the Granulitic into the Serpentine. The first is met with on the shore at Kildown Cove, to be seen at low water. It was much hidden by shore débris, some of which I took the trouble to remove, but was unable to clear that portion where the connection with the Granulitic mass might have been seen.

As seen in the opposite representation it appears to be an intrusive tongue of banded rock, running for several yards through the Serpentine. It consists for the most part of the dark dioritic matter of the Granulitic, with thin veins of the acidic material running roughly parallel through it, which

contain well-developed Hornblende crystals. It curves southwards from the direction of an exposure of a mass of the Granulitic some few feet away, of which there can be little doubt it forms a part. The other instance of a similar character is that of the third dyke in the cliff south of

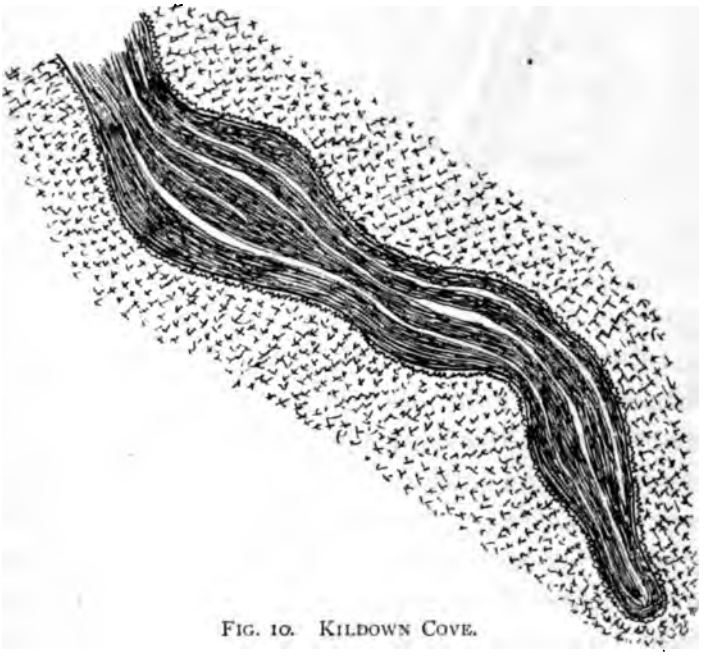

FIG. 10. KILDOWN COVE.

Kennack Sands. I have the impression it has been referred to as an instance of truncation of the banded rock by the Serpentine, but a closer examination does not support that interpretation of its sudden termination, for the bands of light and dark material may be traced through it unbroken in a similar manner to those shown in the following illustration.

FIG. 11. SOUTH OF KENNACK SANDS.

In this, as indicated by the shading, the basic matter again forms the greater part of the mass. The foliation is eloquent in regard to the arrested progress of an intrusive dyke proceeding from the main mass seen exposed on the foreshore. There is some appearance of it being a shoulder, formed by effective resistance to a portion of a larger mass proceeding below the surface further through the Serpentine in the direction indicated by the exposed portion. Other instances of a similar nature might be added, but these two will be sufficient testimony of the kind.

Contributary evidence in support of the view held by the writer might also be adduced from an instance of inclusion in one of the Granitic veins found in the Hornblende Schist. As already mentioned, there are

reasons for thinking that the acidic matter of the Granulitic magma was in a more fluid state than the dioritic, when the whole mass welled up and formed the banded series of rocks. This may account for the frequent appearance of acidic veins in the Hornblende Schist and Serpentine, the mobile matter being able to penetrate cracks and fissures not possible to the more viscous mass. There is the authority of Messrs. Bonney and McMahon for assuming these veins to have been formed at the same time as the Granulitic mass, for they say: "The granite veins in the Hornblendic group are approximately synchronous with those in the Granulitic group, and so anterior to the date of the Serpentine." I have an impression these veins occur for the most part near the boundaries of the Granulitic, as though the acidic matter there found easier means of escape from the folds of its basic companion than that enveloped in the more central portions. However far from or near to the real facts of the case this surmise may be, the examination of one of these veins may be of service in helping to determine the point under consideration. The vein in question is a small one, running irregularly upwards through the Hornblende Schist on the northern side of Church Cove. It is of a light red colour, with strikingly granulated appearance. The foreign matter in it is a mass about two inches in diameter, exceedingly fine grained, very soft, and of a dark brownish-red colour, breaking with a slightly conchoidal fracture.

The contact line is distinct in places, but in others the two rocks appear to have mingled their substances. Upon discovery I more than suspected the inclusion was a form of Serpentine; however, to avoid a mistake, I got some pieces sliced. I owe to Mr. A. R. Hunt a debt of gratitude for an initiation into the wonders and uses of the petrological microscope, which enabled me, with some additional study and practice, to gather from these slices something of what they had to reveal. A glance dispelled the idea of it being true Serpentine. Instead, I found a finely granular field flecked with semi-translucent dark reddish-brown patches. The granular matrix is fully illuminated between crossed nicols, but without any definite crystalline form to be detected under a low power. A higher power resolves the grains into fine scales, apparently matted together, possessing the property of double refraction in a high degree, giving pale green and pale red colours. The brown patches which give colour to the mineral would be some form of iron, probably an earthy form of hæmatite. Near the junction irregularly-shaped crystals of quartz and felspar are seen scattered through the granular material, which penetrates some distance between the constituents of the Granulite, and is also seen in adjacent joints and fine veins. I have no doubt from the appearances described, and after comparing it with some slides kindly lent me by Mr. Howard Fox, that the mineral is Steatite; and as this is so intimately associated with Serpentine,

the junction of which with the Hornblende Schist is found not far from the position of the vein, it is fair to presume that the acidic matter forming the vein gathered the Steatite, or the material which formed it, while passing through Serpentine before penetrating the Hornblende Schist.

From all the considerations herein submitted, taken singly and collectively, it seems to me it must be granted there are reasonable grounds for thinking the Granulitic series a later rock than the Serpentine, and therefore intrusive in it. I am much pleased to find corroborative evidence in a paper by Messrs. Howard Fox and J. J. Harris Teall, F.R.S. In the *Quarterly Journal of the Geological Society*, vol. xlix., May, 1893, they figure and describe a wedge of the Granulitic appearing through the Serpentine on the west coast near the Lion Rock, Kynance. This evidence alone would appear to be most significant and cogent, warranting their conclusion that "the structure of the mass appears to be incompatible with the theory that the Serpentine was intruded into solid Granulitic rock." This provoked another paper from Professor Bonney,[1] which is one likely to make a novice taking an opposite view pause and calculate the consequences of his temerity. However, I gather comfort and courage by feeling assured I have followed the directions expounded in an excellent discourse embodied in this reply upon how to discriminate and estimate the value

[1] *Quart. Journ. Geol. Soc.*, vol. lii., 1896.

of evidence and apply the laws of inductive reasoning. So far my purpose has been to show why I could not accept a particular conclusion set forth by Messrs. Bonney and McMahon as already quoted. In this later (1896) paper by Professor Bonney I find the theory formerly enunciated to be somewhat modified. Instead of the Serpentine penetrating the Granulitic "substantially in its present condition" (1891), in 1896 it is assumed that the Serpentine, which was viscid and tough, "softened the granulite locally, squeezing it about." The modified theory, in consequence, supposes two softenings of the rock, or at least one part of it. First when the acidic matter became intrusive into the basic it was softened sufficiently to allow of both flowing together, and subsequently the compound rock thus formed was again softened wherever the Serpentine came into contact with it. This assumption of a second softening is necessary in the theory to account for the flexures in the bands, and to some extent for the thickening and thinning which accommodates the interfering substance, but it seems to me entirely inadequate to account for the puckerings and inward folds of the bands. Not only so, but is there not some difficulty in understanding how a magma, supposed to be in a "semi-fluid condition, viscid and tough," and consequently comparatively cool, could even from the streams of larger volume, much less from the mere strings of only a few inches in diameter, emit sufficient heat to soften rocks in contact whose

melting-point is even higher than that of the intruding magma? Allowing this difficulty to be surmounted, there follows this anomaly, that to all appearance, from peculiarities before commented upon, the softening influence due to heat must have operated with greater effect upon the acidic matter, which I understand to be the more refractory of the two, fusing at a temperature higher than that of the basic matter supposed by this theory to partially liquefy it. This softening effect is said to have "generally extended for only a few inches away from the actual junction surface," but the following instances of folding do not follow the general rule. They would be at least four feet across (probably more), but I am trusting for dimensions to memory only.

FIG. 12. KILDOWN COVE.

FIG. 13. FORESHORE. LITTLE COVE NEAR CAERLEON COVE.

In respect to the "viscid and tough" magma the Serpentine matter is assumed to have been when invading the Granulite, I am led to consider how this accords with the great number of instances in which it must have penetrated the Granulite, as seen by the sections between Church Cove and Kennack Sands, and whether it is in keeping with the habit of a magma, which has never been known to send out a branching vein,[1] that it should send through a rock as unyielding as the Granulite such small processes and in such close conjunction as shown in Fig. 9.

Another question arises in connection with this supposed condition of the Serpentine magma. Is it a well-established fact and generally accepted, that a magma in a condition of tough viscidity is

[1] Vide *Quart. Journ. Geol. Soc.*, vol. lii., 1896, p. 29.

capable of becoming welded to a rock it comes in contact with? For this same magma must, by the assumption, have penetrated the Hornblende Schist at the same time it did the Granulite; and though there is hardly an instance of its adhering even to the latter, yet weldings with the Hornblende Schist were formed as already mentioned.

These questions may be a reflection upon the limited knowledge of the inquirer; nevertheless they indicate real difficulties in endeavouring to reconcile Professor Bonney's theory with my own observation and other undisputed facts. I am much more a disciple of the learned Professor than a critic of his views, and would still prefer to be, but silence in respect to this one point of contention would mean the suppression of what seems to me important evidence, which may help to solve a problem that is still a puzzle to others, if not to the Professor. In regard to the sections figured in his last paper on the subject (1896), I can only say that if I have seen that shown in Fig. 4^2 I must have read it in a different way. I have never met with sections corresponding to Figs. 5 and 7^1, and in respect to Figs. 6 and 8^1 they appear to me to allow of a different interpretation from that given.

It was my intention, as the title implies, to bring forward other evidence that would help to determine more definitely the chronological relation of the various crystalline rocks of the Lizard,

[1] Vide *Quart. Journ. Geol. Soc.*, vol. lii., 1896, pp. 29, 30.

but having already exceeded the desirable limits of a paper of the kind, and in view of paying another visit to the district, I will leave that part of the subject to the future, should circumstances favour its completion. To conclude this I will put in summary form the considerations which seem to me to run counter to Professor Bonney's theory, followed by those which in my judgment support an opposite conclusion.

Considerations adverse to the theory that the Serpentine was intruded into the Granulitic :—

(*a*) The contact with the Hornblende Schist being so different from that with the Granulite.

(*b*) The Serpentine never breaking the bands of the Granulite.

(*c*) Loops of the Granulite bands folding into the Serpentine.

(*d*) The absence of unmistakable fragments of the Granulite in the Serpentine.

(*e*) The improbability of intrusions into such a rock as the Granulite appearing together, as shown in Fig. 9.

(*f*) The absence of longitudinal sections of the Serpentine flow.

(*g*) The improbability of a viscid tough magma sending out so many and such small intrusive processes.

(*h*) The improbability of a comparatively cool magma in such small quantities softening a rock, part of which has a higher fusion-point than the intruder.

(*i*) The anomaly of the softening process affecting the more refractory rock to a greater extent than the part of lower fusion-point.

(*j*) The folds and plications in the Granulite being in some places of considerable extent implies a softening to considerable depths occasionally.

Reasons for thinking the Granulite invaded the Serpentine :—

(*a*) The large number of included masses of Serpentine favours the view.

(*b*) The whole phenomena connected with the folding of the bands round the Serpentine is thus simply explained.

(*c*) The intervening material at the contact planes in the Granulite and its absence in those of the Hornblende Schist argues different conditions.

(*d*) The termination of masses of Serpentine declares them to be pieces, not veins.

(*e*) Tongues of Granulite traverse the Serpentine.

(*f*) Flexures and plications of the Granulite near junctions point to the resistance of the solid Serpentine to flowing Granulite rather than the action of the Serpentine magma upon the solid Granulite.

(*g*) The Steatite in an acidic vein through the Hornblende Schist at Church Cove is favourable evidence.

(*h*) The narrowing-as-they-deepen or cup-shaped hollows in the Granulite partly occupied by Serpen-

tine suggest a termination of the hollow rather than continuous sides of a channel.

(*i*) Hornblende Schist with Serpentine in conjunction, seen amidst the Granulite in the Head south of Cadgwith Cove, and the protuberance of Granulite through Serpentine in north side of Frying Pan, support the view.

(*j*) There being no Dioritic dykes cutting the Granulite, although seen so frequently traversing the Serpentine, is significant.

Royal Geological Society of Cornwall.

THE EIGHTY-EIGHTH

ANNUAL REPORT

ETC.

PENZANCE.

1902.

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The Secretary requests the favour of his being informed of any inaccuracies in the foregoing lists.

THE

ANNIVERSARY ADDRESS OF THE PRESIDENT,

C. LE NEVE FOSTER, ESQ., F.R.S.

To the General Meeting, November 13th, 1901.

LADIES AND GENTLEMEN,—In delivering an address in the year 1901, a President has the choice of many subjects. The dawn of a new century naturally suggests a review of that which has come to a close, and I might therefore have been tempted to deal with the progress of Geology during the last hundred years; but this field has already been occupied, for we listened with pleasure last November to Mr. Enys' sketch of the principal landmarks in Geology during the nineteenth century.

The termination of Her late Majesty's glorious reign presents another fruitful theme, and it occurred to me that I might profitably devote some time and thought to a consideration of the changes which have taken place in the practical geology, in other words mining, of the county of Cornwall during the Victorian era.

Though it is natural for a person getting on in years to dwell on the past, I have resisted this prompting, and the subject which I have chosen is one which, important as it is at the present time, will become of greater commercial significance in the future if miners and geologists will join hands in studying it. I wish to look ahead and try to be of use to posterity, rather than to sum up what has been done by my own generation. My choice of a subject is, "The Experimental Elucidation of certain Vein Phenomena," and the selection came about in this way. After the last meeting of the Society, Mr. Hill, of the Geological Survey, asked me how, in my opinion, the Official Surveyors could

be of service to Cornwall. "What does the Cornishman want to know?" was his question. My answer was that the Cornishman, whether miner, agent, "adventurer," "lord," or merchant, would like the Survey to study the ore deposits of the county, with the object of ascertaining how far it is possible to predict where a mineral vein or lode is likely to be rich. I trust that my idea of the Cornishman's need will meet with your approval. But the question interests a far larger body of people than merely the inhabitants of Cornwall. In all quarters of the globe work is being done in mineral deposits which are not uniformly rich—some parts are worth working, other parts are not, and the problems facing the miner and the mining geologist are these:—How can I decide where the rich parts are most likely to be found? How can I prevent waste of money by avoiding parts likely to be poor? The matter is one of world-wide importance.

Supposing investigations to prove that the rich parts of mineral veins are associated with certain conditions, any hypothesis offering reasons for these facts must be welcomed. If the miner can bring forward to the capitalist good scientific grounds for supposing that there are riches ahead, the latter will be far more likely to open his purse and take the risk of further investigations, than if he had to depend upon some mere personal dictum for which the speaker could supply no definite or solid basis.

I propose during the next few minutes to dwell upon two well-recognised conditions which affect the richness of mineral veins, and to bring before you a few very simple experiments which will serve, not only as possible explanations of observed facts, but also as a means of impressing those facts upon the younger generation in a manner which is not possible without visual aids to knowledge.

It is a well-accepted fact among miners that the richness of a mineral vein is frequently affected by the nature of the surrounding rocks, or "country," if I am to speak in the tongue of the Cornish miner. I may mention one very striking example. In the Lydenburg district of the Transvaal,[1] the so-called "diggers'

[1] KUNTZ, "Ueber die Goldvorkommen im Lydenburger District," *Zeitschr. f. prakt. Geologie.* Berlin, 1896, p. 441.

leaders" are small gold-bearing quartz veins, varying in thickness from that of a sheet of paper to six inches, and lying about fifty feet apart. They intersect beds of slate, sandstone, dolomite, and decomposed greenstone. In the greenstone the veins are worthless; in the dolomite they are poor; in the sandstone they contain 1 to 3 ozs. of gold, and in the slate 10, 20, 30, and even 40 to 50 ozs. of gold per ton. In some unexplained manner the nature of the "country" affects the productiveness of the vein. Numerous other cases might be cited in which the extent and direction of a "course" or "shoot" of ore in a vein coincide with those of some stratum or rock-mass forming the walls. The miner then speaks of the rock as "congenial"; instances are described in every text-book on Mining.

Phenomena of this kind have been observed in so many places in all parts of the world that the idea of regarding the connection between the rich part of the vein and the so-called "congenial" stratum as a mere chance coincidence must be dismissed at once. There evidently is a reason, and it remains for the geologist to unearth it. Much labour has already been expended upon the problem, and various hypotheses have been suggested. When the "congenial" stratum is a hard rock, such as a bed of limestone, and the unsuitable stratum soft, such as a bed of shale, it is sometimes conjectured that the reason is purely mechanical; the original vein fissure might be expected to remain open in hard rock and offer a cavity to receive a deposit of mineral, whilst the walls would fall in and choke up the fissure if soft and friable.

The phenomena may likewise depend upon mere porosity or upon chemical grounds. I will deal with porosity first.

A mineral vein, as is well known to most of my hearers, is very frequently a water channel. I was taught by Cornish mine agents many years ago that, when driving a cross-cut, an increase in the amount of water flowing out of the rock was often a sign that a lode was being approached, and I look upon their teaching as correct. The more porous the rock, the more abundantly may it supply the vein fissure with mineral solutions from some adjacent source, or the more quickly may it drain it, and so

lessen the quantity of ore deposited. I will make my meaning plain by a model. Suppose a little block made of a mixture of five parts of sand with one part of plaster of Paris to represent the rock on the side of a fissure. I make parts *A B C*, *D E F* impervious to water by running in paraffin wax and ironing the surface; the portion *C B G E D H* is still porous. Now bore a set of holes *I*, *J*, *K*, *L*, *M*, *N*, in the block and fill them with a weak solution of acetate of lead. The solution gradually oozes through the pores of the artificial rock over the area *B C H D E G;* none comes out over the surfaces *A B C* and *D E F*. Expose the surface *A G F H* to the action of sulphuretted hydrogen or an alkaline sulphide; the part *C B G E D H* becomes blackened owing to the formation of sulphide of lead (galena) and represents an ore shoot. The parts *A B C* and *D E F* remain uncoloured.

There is nothing unlikely in supposing that a vein fissure may extend down to some source of sulphuretted hydrogen. Those who have visited volcanic regions are aware that vast quantities of this gas are constantly being given off; I have known the top and parts of the sides of Vesuvius to receive a big lemon-yellow cap of sulphur in a single night, and the quantity of sulphur actually deposited must have been small compared with that contained in the sulphuretted hydrogen which escaped without leaving any trace of its existence.

The sulphuretted hydrogen rising through the water filling the fissure will precipitate sulphide of lead, galena, on the porous rock, if that porous rock is supplying lead in solution, and nothing upon the impervious parts of the "walls" of the vein cavity. Permeability and impermeability of the sides or "walls" of a vein are therefore two factors which may affect its ore-bearing qualities. The porous rock in my experiment is "congenial" because it formed a channel for bringing in a metal-bearing solution.

It must not be imagined that I am of opinion that the lead in mineral veins has been deposited from a solution of the acetate; I simply chose that salt as it was one ready at hand and convenient for experimental purposes. Any soluble lead

salt will serve to illustrate my idea; what the salt happened to be in reality I do not profess to know. And further, I am not in this first instance supposing that in nature the supply of the mineral solution was contained in the immediate proximity of the lode, as shown in my model. I am assuming that it may have wandered in through the porous stratum from some distance.

There may be a more immediate connection between the "congenial" rock and the contents of the vein, for the rock may in some cases have supplied the valuable ingredient, and in others it may have supplied a precipitant that gripped and anchored down the useful metal which was previously drifting through the fissure in a state of solution. The first of these two hypotheses is a very favourite one; it was warmly espoused by F. von Sandberger, and cleverly combated by Stelzner. The former endeavoured to show that the rocks adjacent to certain mineral veins contained a store of the heavy metals, distributed, it is true, in minute proportions, but still sufficient, considering the extent of the rocks, to furnish valuable materials for the vein fillings. The nature of the hypothesis will be quickly grasped from my first model, if we now assume that the stratum *CBGEDH* contains some given metal in a form which renders it possible for it to be leached out by percolating solutions. These solutions eventually reach the vein cavity, and deposit their contents at no great distance from the source of the supply.

I will now take the other case in which the "congenial" stratum may be supposed to have played the part of a precipitant. A very marked case is that of the so-called "indicators" at Ballarat, probably familiar to every mining student. These are narrow bands of carbonaceous shale full of iron pyrites; quartz veins which are poor and worthless when crossing other rocks suddenly become rich in gold when they traverse an indicator. It is not improbable that the carbon alone, or the carbon and the pyrites together, caused the precipitation of gold which existed in a state of solution in the water filling the vein fissure. I have endeavoured to elucidate this line of thought by a very simple experiment. Take a piece of lead from an ordinary cedar

pencil and embed it in plaster of Paris, as shown. It may be taken to represent the section of the "indicator" seen on one side of a fissure which eventually becomes filled up and forms the mineral vein. Now stand the block in a weak solution of chloride of gold. After a short time metallic gold will be seen deposited upon the graphite, whilst the plaster remains free. The action of the graphite is very apparent, and one cannot help advancing the hypothesis that the carbon in the "indicator" may have acted in a somewhat similar manner. At all events, the experiment will serve to impress by visual means upon the brain of the student a fact which has been well recognised in Australia for many years. Again I must add that I am in no way laying it down as a fact that the gold existed in the earth's crust in the form of a chloride; this salt was ready at hand for the experiment, and I made use of it. It has not yet been decided, as far as I know, what soluble gold compound has percolated through the earth's crust and deposited the metal.

Another fact regularly taught in the schools, and well known in Cornwall, is that junctions of mineral veins are lines of enrichment. Why should this be so? It may be suggested that in some cases the intersecting vein may have caused the enrichment by supplying a precipitant in larger quantities than existed in the other parts of the original vein.

Thus, representing the two veins by mere lines, *A B* may be supposed to be the fissure at a certain level and *A' B'* the same fissure somewhat lower down. I suppose that from some source, it matters not whence, as far as my argument is concerned, the fissure is receiving a supply of a metal-bearing solution, and that there is little in the surrounding rocks to cause any precipitation of the metal. Earth movements cause the production of a second fissure, *C D C' D'*, which reaches down to some source of sulphuretted hydrogen, or of a soluble sulphide. It is only natural that you will have a precipitation of metallic sulphides along *E E'*, the line of intersection of the two planes. This hypothesis is more easily followed in a model. I take a block of plaster of Paris and make two saw-cuts across it representing *A B*

and *C D*. Along the plane *A B A' B'* I place a few sheets of blotting-paper soaked with a solution of acetate of lead. This is intended to represent the vein cavity with a lead solution making its way along it. Now suppose it is severed by a new fissure, *C D C' D'*, the lode is cut through along the line *E E'*; insert along the plane *C D C' D'*, in a sheet of blotting-paper soaked with a little weak ammonium sulphide, a common laboratory reagent. Close up the block of plaster of Paris, and of course you get precipitation of lead sulphide, galena, where the two fissures meet.

You may tell me that these matters are so unutterably simple and so readily understandable as to be scarcely deserving a place in a Presidential address, but my experience is that the young miner does not always give them sufficient thought. He is too ready to expect that his lode is going to be rich throughout, and even when he finds that such is not the case, he fails to record the change of conditions which appears to have led to enrichment or impoverishment. It is this record that I am anxious about. Scores of young men are leaving the mines and excellent schools of this county every year in order to take the management of mining properties abroad, and I earnestly implore them, and those who stay at home, to keep records of this kind. Let them note carefully upon paper exactly when and where a certain lode becomes rich or poor, and let them collect specimens ready to be submitted to the geologist. Whether the latter will immediately be able to give reasons for the change in yield I do not know, but at all events a record of facts will be obtained, which some day may be of service for building up a valid theory of ore deposits and in enabling useful commercial predictions to be made. To attain this end the miner and the geologist should go hand in hand, and if they do so, I venture to prophesy that both will be benefited. To use an expression of the day, "There is money in the matter," and this must be my excuse for harping upon a theme which will present no feature of novelty to many of my audience, beyond my attempt to convey my meaning through the eye instead of through the slower and less reliable organ, the ear.

I have to thank Mr. Hibbert, one of my assistants at the Royal College of Science, for having prepared the illustrations for this address.

The President, on behalf of the Society, then presented the William Bolitho Gold Medal for 1901 to Mr. Thomas Clark, of Truro, of whose work he said:—

Mr. Thomas Clark, a native of Truro, began life as a quarryman and stonecutter and marble mason. At an early age he took great interest in geological phenomena, and became an earnest student of geological science. He devoted a considerable amount of time to working out sections across the county from Newquay to Tresilian Bridge, from Gravel Hill iron mines to Truro, and from Trewavas Head to Looe Bar, for which he received, in 1874, the Royal Cornwall Polytechnic Society's Bronze Medal. He also studied the rocks of the Lizard district and made a microscopical examination of these rocks, for which he was awarded the First Silver Medal of the same Society in 1884. In 1886 he made a collection of the building and ornamental stones of the county, and gained the Polytechnic Society's Second Silver Medal.

Mr. Clark is also an expert in the cutting of rock sections for microscopical investigation, and has been employed by the Cornwall County Council as a teacher of that branch of geological work. In 1883 the Mining Institute of Cornwall awarded him its Bronze Medal for a fine collection of rock sections cut by him.

Mr. Clark was highway surveyor for the West Powder highway district for a number of years, and paid considerable attention to the quality and relative values of the different rocks used in the county for road metalling. He invented a machine for testing their hardness and tenacity, and in 1882 obtained the Polytechnic Society's Bronze Medal for that machine, and in 1886 was awarded that Society's First Bronze Medal for a collection of road-metalling material and testing machine.

Mr. Clark has been an enthusiastic worker in the geological field, and has a large practical acquaintance with the rocks

of his native county; he has always been ready to assist and encourage the young student, and his knowledge and services have been at the disposal of all who have consulted him in matters relating to the geology of the county of Cornwall.

Mr. Clark replied:—

Mr. President, Ladies, and Gentlemen,—It was a great surprise to me when I first had the intimation that I was to receive this year the William Bolitho Gold Medal. I was not aware that I had ever done anything directly for this Society that would commend itself to your notice, but if anything that I have done in the field or with the microscope for somewhat kindred societies has attracted your notice, I may then feel doubly proud of it, and to be thus recognised by the second oldest Geological Society in England, which has had amongst its members and associates some of the ablest men of the past century, is an honour indeed which I deeply appreciate.

I would like to say in connection with the rock-section work, in which I have achieved some little amount of success, that the first lapidary machine introduced into Cornwall was by the late Mr. Enys, of Enys, who presented it to Mr. J. H. Collins, and when he left Truro for Rio Tinto I purchased it; and it is from that same machine that I had others constructed to carry on the work at both Redruth and Truro Mining Schools. In conclusion, with all due reverence to the donor, I thank the President and the Committee for the hearty and spontaneous manner in which they have this day conferred on me their highest honour, viz. the William Bolitho Gold Medal.

REPORT OF THE COUNCIL

To the Annual Meeting, November 13th, 1901.

THE death of Her Majesty Queen Victoria in January last has been unquestionably the great event of the year. The sincere expressions of regret from every corner of the empire showed how thoroughly Her Majesty's noble life had been appreciated by her people. This Society has a particular reason for placing on record the loss which we all sustained, having enjoyed the privilege of her Royal Patronage during the whole of her long and illustrious reign. Your Council, feeling sure that their action would be in complete accordance with the wishes of the members, took the first opportunity of presenting through the President a short address to His Majesty King Edward VII., assuring him of the feelings of the Society to Her late Majesty and of continued loyalty to her successor on the throne.

In reply, His Majesty was graciously pleased to accede to the request of the Society to grant his Royal Patronage.

At the same time your Council approached His Royal Highness the Duke of Cornwall with an expression of the loyal sentiments of the Society, and a hope that the Society might enjoy the privilege of claiming his support as Vice-Patron, to which His Royal Highness was pleased to accede a gracious acquiescence. As a Cornish Society your Council are flattered to record, in passing, that their Royal Highnesses were pleased to make their famous visit to the "realms across the seas" bearing the title which they derive from the Duchy of Cornwall.

Although the fond hopes of a revival in Cornish mining which have been before the eyes of all for the past three years are

still unfulfilled, your Council note with pleasure the success and development of the mining schools throughout the county. The school at Camborne has, both from the excellence of the teaching and the number and success of the students, enjoyed a high and established reputation for several years. The Redruth school, though smaller, is likewise doing work. The school at Truro, somewhat farther from the actual mining district, has excellent teaching accommodation in the Central School opened there two years ago; and during the past year the school at Penzance has been greatly improved, and is now well fitted with many of the necessary requirements for teaching chemistry, metallurgy, assaying, and mine surveying. The Council are specially pleased to record the success of this last, as it has grown up directly from the science classes which for many years were conducted in these premises under the auspices and with the assistance of this Society; and they congratulate Mr. A. K. Barnett, a member of this Society, to whom the whole development from the very beginning is due, on the success which has attended his energetic efforts.

Of new specimens added to the Museum the excellent sections of local rocks, prepared and presented by Mr. Thomas Clark, are particularly valuable and interesting. The Library, as will be seen from the report of the Librarian, continues to grow rapidly.

The Council regret that they have not been able to devise any satisfactory plan for providing the much-needed increase of accommodation both in the Museum and in the Library. The gratifying increase in the collections of the Society is making this a question of urgent importance.

The new Geological Survey of Cornwall is being energetically proceeded with, no less than one-third of the whole staff of the Survey being now at work in the county.

The Council are pleased to announce that, in addition to the other surveyors, Mr. Clement Reid has come down to undertake the extreme western parts, which had not already been investigated by Mr. Wilkinson.

The Council have decided to award the William Bolitho Gold Medal for 1901 to Mr. Thomas Clark, of Truro They thus

have the pleasure of recognising the work of a practical geologist, who has acquired a profound knowledge of the science during a busy life without the assistance of many of the advantages which other students have enjoyed; and has applied his knowledge to the practical requirements of his profession.

They regret to record the death of Mr. W. Eddy, of Boscaswell, a member of the Council, to whom the Society is indebted for several valuable and interesting specimens in the collection of minerals.

Quite recently Captain Josiah Thomas has passed away, who, although not a member of the Society, filled so prominent a place in Cornish mining that the Council cannot allow the occasion to pass without an expression of their regret at his death.

LIBRARIAN'S REPORT

From November 1st, 1900, to October 31st, 1901.

THE following works have been added to the Library during the year:—

I. TRANSACTIONS, JOURNALS, AND REPORTS.

Presented by the respective Societies, Editors, and other Donors, or Purchased.

Adelaide. South Australian School of Mines and Industries and Technological Museum.

Twelfth Annual Report, 1900. 8vo. Adelaide, 1901.

Boston. American Academy of Arts and Sciences.

Proceedings: Vol. xxxvi., Nos. 5–29, July, 1900, to June, 1901. Including Title-page and Contents of vol. xxxvi. Roy. 8vo. Boston, 1900–1901.

Bristol. Naturalists' Society.

Proceedings: New Series, vol. ix., part 2, 1899. Including Title-page and Index of vol. viii. 8vo. Bristol, 1901.

Brussels. Société Royale Malacologique de Belgique.

Bulletins des Seances, pp. 129–175. Année 1899.
" " pp. 1–107. Année 1900.
8vo. Bruxelles, 1900–1901.

Buenos Aires. Museo Nacional.

Comunicaciones: Tomo i., No. 7.
" " " 8.
" " " 9.
8vo. Buenos Aires, 1900–1901.

Buffalo. Society of Natural Sciences.

Bulletin: Vol. vii., No. 1. With a Geological Map of the Niagara River. Roy. 8vo. Buffalo, N.Y., 1901.

Cambridge. University Library.

Report of the Library Syndicate for the year ending December 31st, 1900. 4to. Cambridge, 1901.

Canada. Canadian Institute.

Proceedings: New Series, vol. ii., part 4, No. 10. January, 1901. Roy. 8vo, Toronto, 1901.

Transactions: Vol. vii., part 1, No. 13. August, 1901. Roy. 8vo. Toronto, 1901.

——. Geological Survey of Canada.

Relief Map of Canada and the United States. Elephant Folio. Ottawa, 1900.

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„ „ „ vi. „ May, 1901.
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other Districts," by W. H. Weed, accompanied by "A Report on the Petrography of the Igneous Rocks of the District," by L. V. Pirsson. Part 4—Hydrography: "Report of Progress of Stream Measurements for the Calendar Year 1898," by F. H. Newell; "Hydrography of Nicaragua," by A. P. Davis. Part 5—Forest Reserves (with Maps): "The Forests of the United States," by H. Gannett; "Pikes Peak, Plum Creek, and South Platte Reserves," by J. G. Jack; "White River Plateau Timberland Reserve," by G. B. Sudworth; "Battlement Mesa Forest Reserve," by G. B. Sudworth; "The Flathead Forest Reserve," by H. B. Ayres; "The Bitteroot, San Gabriel, San Bernardino, and San Jacinto Forest Reserves," by J. B. Leiberg. Part 7—Explorations in Alaska in 1898: "Reconnaissance in the Sushitna Basin and Adjacent Territory, Alaska, in 1898," by G. H. Eldridge; "A Reconnaissance in South-western Alaska in 1898," by J. E. Spurr; "A Reconnaissance from Resurrection Bay to the Tanana River, Alaska, in 1898," by W. C. Mendenhall; "A Reconnaissance of a part of Prince William Sound and the Copper River District, Alaska, in 1898," by F. C. Schrader; "A Reconnaissance in the Tanana and White River Basins, Alaska, in 1898," by A. H. Brooks. 4to, cloth. Washington, 1900.

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No. 164. Reconnaissance in the Rio Grande Coal Fields of Texas. By T. W. Vaughan.

No. 165. Contributions to the Geology of Maine. By H. S. Williams and H. E. Gregory.

No. 166. A Gazetteer of Utah. By H. Gannett.

No. 167. Contributions to Chemistry and Mineralogy from the Laboratory of the United States Geological Survey. By F. W. Clarke.

No. 168. Analyses of Rocks, from the Laboratory of the United States Geological Survey, 1880–1899. Tabulated by F. W. Clarke.

No. 169. Altitudes in Alaska. Compiled by H. Gannett.

No. 170. Survey of the Boundary-line between Idaho and Montana from the International Boundary to the Crest of the Bitteroot Mountains. By R. U. Goode.

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No. 172. Bibliography and Index of North American Geology, Paleontology, Petrology, and Mineralogy for the year 1899. By F. B. Weeks.

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Funafuti: The Story of a Coral Atoll. By W. J. Sollas.

Oceanography. By M. J. Thoulet.

The Growth of Science in the Nineteenth Century. By Sir Michael Foster, K.C.B.

On Lord Kelvin's Address on the Age of the Earth as an Abode fitted for Life. By Prof. T. C. Chamberlain.

An Estimate of the Geological Age of the Earth. By J. Joly, M.A., D.SC., F.R.S.

The Petrified Forests of Arizona. By L. F. Ward.

Present Condition of the Floor of the Ocean:—Evolution of the Continental and Oceanic Areas. By Sir John Murray, K.C.B., F.R.S.

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——. Report on the Mount William Gold-Field. By H. Herman, B.C.E., F.G.S.

——. Report on the Little Bendigo or Nerrena Gold-Field, Ballarat. (With Plans and Sections.) By H. S. Whitelaw. Folio. Melbourne, 1900–1901.

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——. Map: Mining Map of the Boulder Belt, East Coolgardie G. F., 1900.

II. GEOLOGICAL AND MISCELLANEOUS PUBLICATIONS.

Presented by the Authors or other Donors.

Millett, F. W. Report on the Recent Foraminifera of the Malay Archipelago. Collected by Mr. A. Durrand, F.R.M.S. Parts ix. and x. By Fortesque William Millett, F.R.M.S. 8vo. London, 1900–1901.
[Presented by the Author.]

Clark, T. MS. Coloured Drawings of Rock Sections. 2 vols.

CURATOR'S REPORT.

DONATIONS TO THE MUSEUM.

NAME AND LOCALITY.	DONOR.
Serpulites, from Bedruthan	Howard Fox.
Fish Scale „ „	
Loxonema sp. „	
Orthis arcuata, from Bedruthan	
Pachypora reticulata, from Bedruthan	
Polypora ripisteria „ „	
Gorgonia ripisteria „ „	
Fucoid (?) „ „	
Specimen from Pendarves Island	
Petraia „ Trescore	
Rock Sections, mounted, Cornwall	Thomas Clark.
Atmospheric Dust from Sicily	F. W. Millett.

NOTE ON THE FOSSILS.

By J. H. Collins, F.G.S.

Not many fossils have been added to the collection during the year, yet there have been some interesting additions, these being mainly due to the untiring labours of Mr. Howard Fox. The catalogued and mounted specimens have now reached No. 1,743. I have on former occasions urged local geologists to endeavour to add to our fish remains, and particularly from the fish beds of Polperro and Lanivet Bay. These beds yielded many beautiful specimens to the vigilant examination of Mr. Peach more than fifty years ago, and I feel sure that equal labours in that neighbourhood now would be equally rewarded.

There are other hitherto barren fields to be searched—thus the whole of the Mount's Bay area except Gunwallo Cove still remains "unfossiliferous"—as also the whole of the north coast of Cornwall, south of Perranporth. Discoveries in these fields would greatly aid Mr. Hill and his colleagues in their determination of the geological horizons of West Cornwall.

TREASURER'S STATEMENT, 1901–1902.

Dr. *The Treasurer in Account with the Royal Geological Society of Cornwall.* **Cr.**

November 13th, 1901—	£	s.	d.
To Ordinary Subscriptions and Arrears	46	4	0
,, One Year's Dividend on £1,800 Midland Railway 2½% Debenture Stock, £45 0s. 0d., less tax at 1s. 0½d., £2 6s. 11d.	42	13	1
,, Sale of *Transactions*	0	12	0
,, G. B. Hill, Esq., cost of fifty Papers	0	12	6
	£90	1	7
,, Balance due to Treasurer	54	1	8
	£144	3	3

November 13th, 1901—	£	s.	d.
By Balance from Last Year	18	3	1
,, Rates and Taxes	0	8	0
,, Housekeeper's Salary	20	0	0
,, Curator's Salary	42	13	1
,, Fire Insurance Premium	2	12	9
,, Books, Binding, etc.	34	19	3
,, Coals, Gas, Cleaning, etc.	12	2	4
,, Repairs to Buildings	1	16	7
,, Engrossing Addresses to—H.M. the King	2	2	0
Duke of Cornwall	2	2	0
,, Sundry Expenses—Stationery, Postages, Advertising, Tea at Meetings, etc.	7	4	2
	£144	3	3
,, Balance due to Treasurer	54	1	8

PENZANCE, *November 13th*, 1901.

T. R. BOLITHO, *Treasurer.*

W. BOLITHO GOLD MEDAL ACCOUNT.

Dr.	£	s.	d.	Cr.	£	s.	d.
November 13th, 1900—				November 13th, 1900—			
Garrard and Co.	12	10	0	Balance as April 15th	525	18	9
November 13th, 1901—				October 21st, 1901—			
Garrard and Co.	12	10	0	Interest to April 15th, 1901—	12	18	6
Balance	513	17	3				
	£538	17	3		£538	17	3
				By Balance	513	17	3

LIST OF

PAPERS READ TO THE SOCIETY,

1901.

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1. President's Address. By C. Le Neve Foster, F.R.S.

2. Note on the Fossils. By J. H. Collins, F.G.S.

3. The Sequence of the Lizard Rocks (second paper). By Harford J. Lowe.

4. On the Distribution of Fossils on the North Coast of Cornwall. By Howard Fox, F.G.S.

5. The Plutonic Rocks of West Cornwall in their relation to the Mineral Ores. By J. B. Hill, R.N. (H.M. Geol. Survey).

THE SEQUENCE OF THE LIZARD ROCKS.

(SECOND PAPER.)

By Harford J. Lowe.

The paper under this title read at the last Annual Meeting, which the Society did me the honour of printing in their *Transactions*, scarcely justified its title, in that it dealt with two only of the several kinds of igneous rocks found in the district. It was, however, necessary to deal specially with the relation of the Serpentine to the Banded or Granulitic Rock as a preliminary to dealing with the whole series, inasmuch as it had been specifically stated by eminent authority (in error, as I have endeavoured to show) that the Granulitic was formed prior to the Serpentine, and that the latter was the intruding rock. It was this view, which did not seem to me to be in keeping with the appearances in the field and deductions therefrom, that led me to deal with the question of the order in which these rocks were brought together. Having in an analogical sense untied a puzzling and hindering knot, the strands are now free to be

laid in the order that observation and scientific reasoning may dictate.

The rocks to be dealt with comprise in the main Hornblende Schist, Serpentine, Gabbros, Diorites, and the curiously banded rock termed the Granulitic. I purpose treating each one in order of rational sequence, taking the oldest rock first.

The junction of the igneous series of the rocks of the Lizard with the slates follows a curved line running for some distance in a north-easterly direction from Polurrian Cove on the west side of the peninsula, then veering eastward continues to the valley ending seaward in Porthalla Cove. All south of this line constitutes the Lizard complex of igneous and metamorphic rocks, while north of it is found a sedimentary series of slates, etc. From appearances at the plane of junction and inferences from other considerations, it is probable that the whole igneous mass has been elevated independently of the slate series, a fault having formed along the line of junction; so that it may be inferred that the slate material was once continuous over at least a portion of the igneous district prior to its upheaval. This would imply that the slates may be older than most of the igneous series, which I am inclined to think is the case—the exception being the Hornblende Schist, or it may be more correct to say the materials which have formed the Hornblende Schist. One reason for thinking so will be mentioned presently.

HORNBLENDE SCHIST.

Geologists are at one in giving the first place in regard to age among the Lizard rocks to the Hornblende Schist. It forms the extreme member of the complex on the north-east, the north-west, and south of the area. Its mode of formation has much puzzled geologists in the past, and no generally accepted theory seems to have been propounded yet. However, Hornblende Schist has become to be considered a rock metamorphosed out of volcanic materials, and in connection with his study of the Lizard rocks, Major-General C. N. McMahon has described a process to account for the formation of this Hornblende Schist from a basic Volcanic Tuff.[1]

He assumes a fine Tuff to be laid at the root of a volcano. In its conversion to a crystalline rock he considers heated water to be the main factor. He attributes the stratification of the Hornblende Schist to the percolation and capillary flow of this heated water through the material. The hypothesis comprises two processes: (1) a leaching out of the unstable minerals (pyroxene) from spaces between the planes of lamination, and (2) the formation of stable minerals (hornblende) along those planes. The theory appeals to one as ingenious and satisfactorily accounting for the molecular reconstruction of the materials of the mass, but it leaves insufficiently explained how percolating water could

[1] *Quart. Journ. Geol. Soc.*, 1889, p. 530.

act through a heterogeneous mass and leave its constituents arranged in such wonderful regularity of alternating minerals such as is usually found in the Hornblende Schist—the folia sometimes approaching the thinness of a sheet of paper, and lying in almost perfectly parallel planes. It seems to me necessary to assume some mechanical means of sorting the materials at the outset.

Consider a volcano acting somewhat as Stromboli is doing at present, but with much greater vigour. With geyser-like spasms the volcanic matter of our hypothesis is ejected and shattered by contained expanding gases into finely divided material, which falls in the vicinity of the vent as coarse dust. This material being derived from a magma not perfectly homogeneous, would form particles of differing specific gravities. The heavier would presumably contain a greater proportion of the constituents necessary for the formation of the Hornblende, while the lighter would be nearer in constitution to the felspar. This dust falling in water of fair depth would be roughly sorted into two layers, the heavier reaching the bottom sooner than those particles of less specific gravity. Following up this idea, it is easy to conceive the formation of a deposit with layers of varying thickness sorted out into allied constituents. This arrangement of material subjected to the conditions assumed by Major-General McMahon, viz. heat, water, pressure, and the leaching out of solvent matter, would warrant the assumption of the mass becoming

partially dissolved. There would thus be solid particles of differing constitution, each purified by the solution of adhering matter, arranged in layers, and lying in saturated heated water. When crystallisation became possible in this mass the solid particles would act as the centres of molecular attraction, which would be drawing their differing matter of crystallisation from the solution into the planes along which the centres lie—Felspar crystals forming along the plane in which their nuclei predominated, and Hornblende in the adjoining plane, each clearing the intervening zone of its own particular molecules within the limits of crystalline attraction. Thus, it seems to me, the thin bands of layers of Felspar and Hornblende might be separated out, but where thicker bands of unassorted material prevailed the discriminating power of molecular attraction could not act in planes; instead, centres of crystallisation would be formed, independently of regularity, in areas of greatest saturation, and the minerals would be mixed. If in the latter case the Hornblende crystals prevailed in quantity, they would mask by their colour the crystals of Felspar. This is in keeping with what is observed in the Hornblende Schist of the Lizard, and the hypothesis is suggested as a reasonable way of accounting for the arrangement of the minerals in that rock.

On passing from sections of the slate series to the adjoining Hornblende Schist, one observes the contrast between them in the remarkable

way in which the sedimentaries have been folded and distorted, and the comparative immunity therefrom in the Schist. The folia of the latter in the main masses lie evenly at a low angle to the horizon, and appear to have successfully resisted the pressures which have so disturbed the more yielding slates. It would appear that the Hornblende Schist is of such consistency as to fracture rather than bend, and most of the contacts support this view. Still, locally the Schist may be found considerably altered by earth strains, more particularly at Old Lizard Head, where it is seen crumpled into corrugations, and the folia somewhat obliterated. It is near here where some patches of Mica Schist are found in the Hornblende rock. These may possibly be portions of the slate series, which, having got faulted into the Hornblende rock, have been subjected to conditions which converted them into a Mica Schist. There are other instances of Mica Schist in the Hornblende rock on the north-western border which may be accounted for in the same way.

So far we have been dealing with a rock of peculiar formation, but the others of the district are alike in that they are formed from molten magmas which have penetrated the Schist and each other.

SERPENTINE.

Having shown in a former paper that the Granulitic was not formed prior to the Serpentine, there is no further controversy respecting the relation of

the Serpentine to the Hornblende Schist, so that it may be taken to be the second in the sequence of igneous rocks. Indeed, I may call it the first of the series of molten magmas that forced its way into and through the probably deeply seated rocks overlying the volcanic area. It has broken through the Schist in several places, and the following

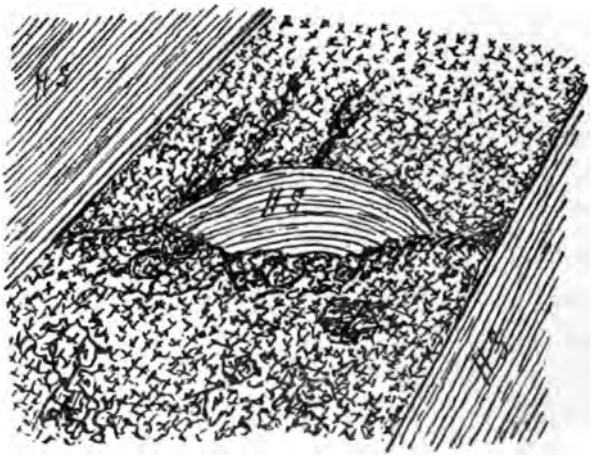


FIG. 1. HORNBLENDE SCHIST IN SERPENTINE. PARC BEAN.

sections, Figs. 1 and 2, show inclusions of the Hornblende Schist in the intrusive Serpentine.

The included mass shown in Fig. 1 has been subjected to such great stresses that the folia are bent, and parts converted into a brown Mica at points of greatest tension. In Fig. 2 will be noticed a sheet of Serpentine magma has forced its way between the folia of the included mass of Hornblende Schist.

Very exhaustive descriptions of the peculiarities

and varieties of the Serpentine of the Lizard have been given by Professor Bonney and others, and an admirable account of the mode of its metamorphosis by Major-General McMahon.

I am dealing in the main with field observation, but in traversing the ground I may reiterate the accepted view that Serpentine is a secondary pro-

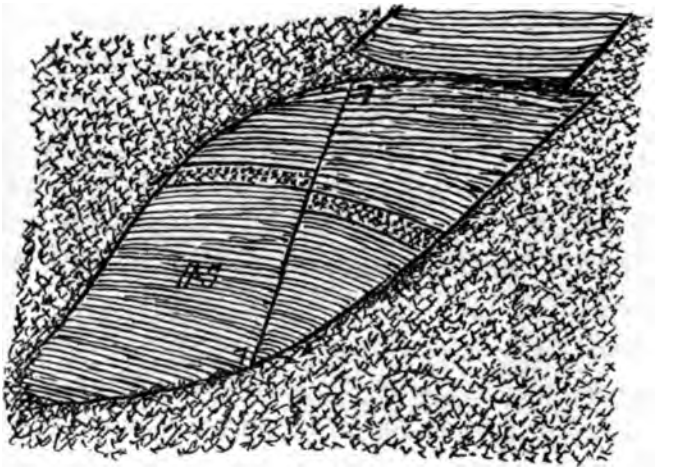


FIG. 2. HORNBLENDE SCHIST IN SERPENTINE. PORTHALLA COVE, SOUTH.

duct which has been formed by the chemical and crystalline change of a rock composed chiefly of a mineral called olivine or peridote. The presence of other minerals in the original rock not so subject to entire alteration determines the varieties. Macroscopically considered, there may be said to be four in the Lizard district, viz. the commonest variety containing glittering crystals of bastite—a similar rock with the bastite not apparent—a

Serpentine usually containing small black gummy specks of picotite—and the Troctolite, conspicuous by its crystals of felspar. Of these the two first mentioned form the great mass, and are probably derived from the same magma, which in parts was richer in the material to form the bastite mineral. The other two varieties were evidently later protrusions of magmas of different components. The Serpentine containing picotite differs in colour and lustre from the commoner varieties, and indeed so contrasts with the ordinary Serpentine as to deceive me on first observing it. Without testing with the hammer and lens, I figured it in my note-book as one of the many Diorite dykes traversing the Serpentine that was cut by a dyke of Gabbro. Being the only instance of the kind noticed, I became doubtful of it, and was anxious to confirm the impression during subsequent visits, but was unable to find the spot until my last visit, when I found that I had correctly figured the section, but had mistaken for Diorite a dyke of this picotite Serpentine. A representation of the section is given in Fig. 3, and a more remarkable section of the same rock is shown in Fig. 4.

With "segregation" and "differentiation of magma" ideas floating in the geological atmosphere, it is well to ask, May not this be an instance of the crystallising process predicated by these terms? Closer observation negatives the idea by reason of the definiteness of the boundary line between the two Serpentines; while the way

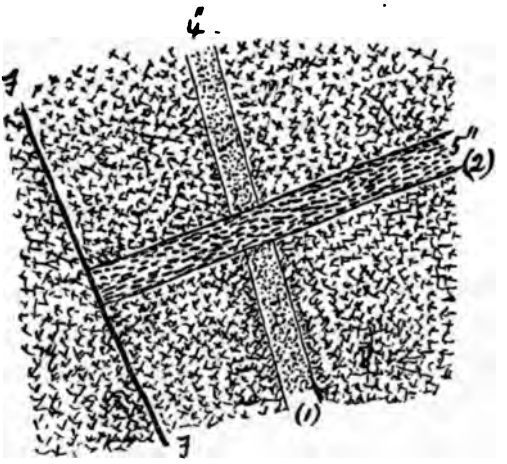


FIG. 3. PICOTITE SERPENTINE (1) IN BASTITE SERPENTINE CUT BY GABBRO (2). PERPREAN COVE.

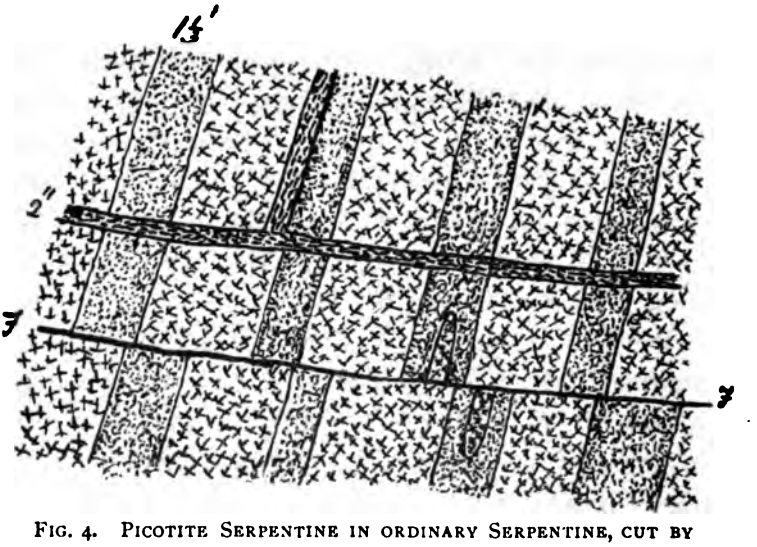


FIG. 4. PICOTITE SERPENTINE IN ORDINARY SERPENTINE, CUT BY GABBRO. SOUTH OF COASTGUARD STATION, COVERACK.

in which the Gabbro vein follows the line of junction, as well as the inclusion of a piece of ordinary Serpentine in one of the dykes, as shown in Fig. 4, are confirmatory of the intrusion mode of explaining the phenomenon.

The Troctolite varies much from the true Serpentines by containing a great proportion of felspar, which in the Lizard variety gives it a conspicuously speckled or porphyritic appearance. It occurs in very limited area and quantity, chiefly in the ordinary Serpentine of Perprean Cove. In the angle of that cove it is seen ramifying the Serpentine in various directions by short processes that arise from the main upflow. An instance is represented in Fig. 5.

I have seen nothing that could be construed into indications of its relation in time to the picotite Serpentine. Its chronological relation to the Serpentine in general may, however, be widely separated

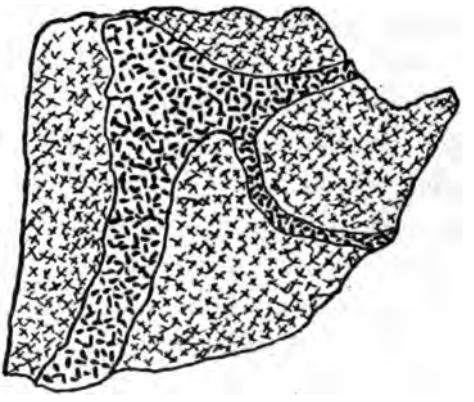


FIG. 5. BLOCK SHOWING TROCTOLITE PENETRATING SERPENTINE. PERPREAN COVE.

if the condition of its olivine may be used as a criterion; for in most instances the olivine is not wholly converted into Serpentine, and in some fine-grained sections it appears to be quite unaltered. This difference in the condition of the olivine may, however, be owing to the difference of constitution of the rock to the true Serpentine rather than much difference in age or conditions to which it has been subjected.

GABBROS.

Following the Serpentine in the order of the protrusions of volcanic magmas came the Gabbros. These have been fully described by Messrs. Teall, Bonney, McMahon, and others. A considerable area on the east of the Lizard is occupied by the main mass of the Gabbro, and innumerable dykes are met with on both sides of that area, though comparatively few are met with on the west of the peninsula.

The Gabbros vary to an extreme degree from extraordinarily coarse crystalline structure to very fine. In some cases the felspar predominates in others the rock may be almost entirely composed of diallage. In some the diallage looks very fresh and metallic, in others it is more like Hornblende. Often the rock appears to be foliated, but more frequently the crystals are irregularly interspersed throughout the mass. Numerous dykes are met with cutting the Serpentine, varying from an inch or less in width to four and five feet. In some the minerals appear fresh, and the rock is then very

tough; in others the crystals are disintegrated and altered, and the rock crumbly. Microscopically the differences are equally pronounced, and Professor Bonney has divided the Gabbros into older and newer.

Fig. 6 represents a section where one dyke of Gabbro cuts two others, evidencing two protrusions of Gabbro through the Serpentine, and I have a

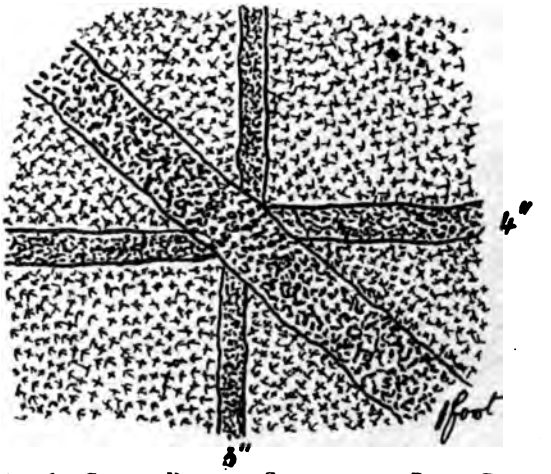


FIG. 6. GABBRO DYKES IN SERPENTINE. PORTH BEER.

note of a double Gabbro dyke with appearances as though a former dyke had either opened and been filled again by another flow of magma, or a second flow had found its way along the junction on each side of the first flow.

As, however, the Gabbro dykes only cut the Serpentines and each other, it would appear, as in the case of the Serpentines, that the later flow of magma was in close connection with the first,

no flow of another magma intervening. Many of the Gabbro dykes lie at comparatively low angles to the horizon, dipping southward with a strike roughly east and west. As an instance of their frequency it may be recorded that there are to be met with in Coverack Bay, eight parallel dykes varying in thickness from a few inches to as many feet within a measure of fifteen paces, the whole being cut by a dyke of Diorite. The following (Fig. 7) represents an interesting section :—

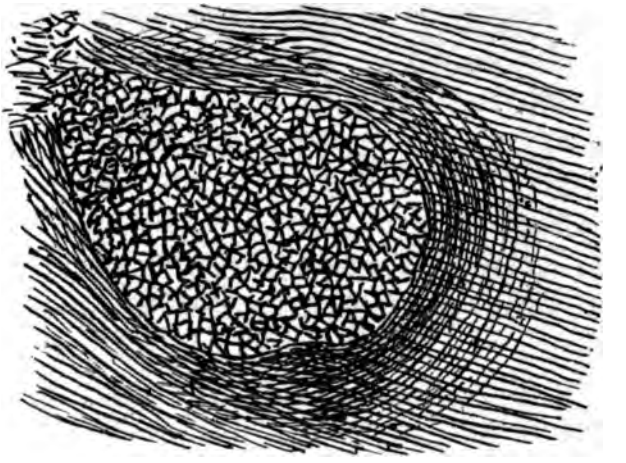


FIG. 7. GABBRO IN HORNBLENDE SCHIST. PORTHKERRIS.

It is an instance of a very coarsely crystalline Gabbro in Hornblende Schist. In it the diallage prevails, occurring in remarkably large crystals, which, however, have not the metallic sheen usually so observable in that mineral, but have more the appearance of a somewhat fibrous Hornblende. The mass in shape suggests a pocket of some four feet

in diameter, and is the only occurrence of Gabbro in Hornblende Schist that I am aware of. As indicated in the figure, the folia of the Hornblende Schist are thrown up to a high angle, and a kind of puckering or cleavage has been formed in it by the injected Gabbro across the foliation and concentric to the mass.

DIORITES.

The Diorites come next to the Gabbros in order of plutonic injection. Their differences are not so apparent. The unaided eye would divide them into two varieties only—one a very dark, finely crystalline rock, and the other of a dark grey colour, with varying sized porphyritic crystals of white felspar unevenly distributed through it. The Diorite is peculiar in that it is not found in mass like the other rocks, but in numerous dykes varying greatly in width, the extreme of which is probably less than twenty feet. I know of no instance of the Diorite cutting the Hornblende Schist, but I think Messrs. Fox and Somervail have met cases in their thorough examination of the district. In the Serpentine and Gabbro, however, they occur in numbers, which are to be seen more particularly on the eastern side of the peninsula. The manner in which they penetrate the former in one locality is shown in the cliff section represented in Fig. 8.

I have already mentioned one notable instance of a Diorite dyke cutting dykes of Gabbro. Instances are to be met with in many places, especially

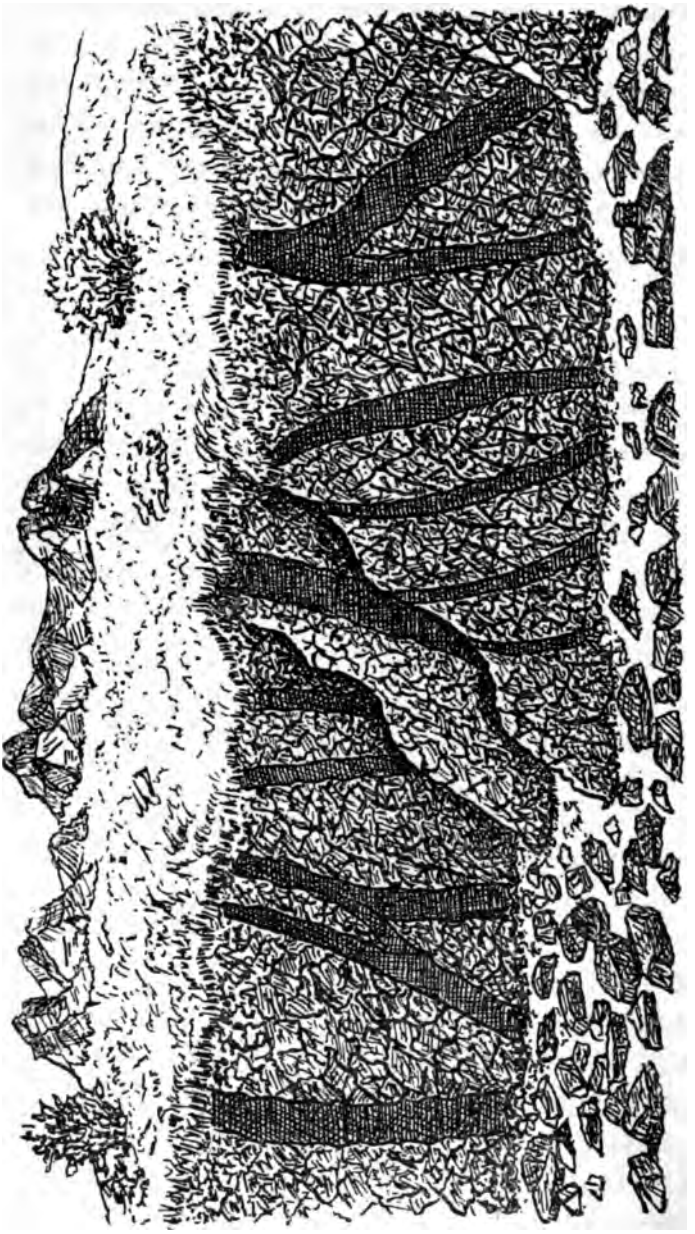


FIG. 8. DIORITE DYKES IN SERPENTINE. CHYNHALLS HEAD.

near Coverack. One of a more unusual character is shown in the following figure :—

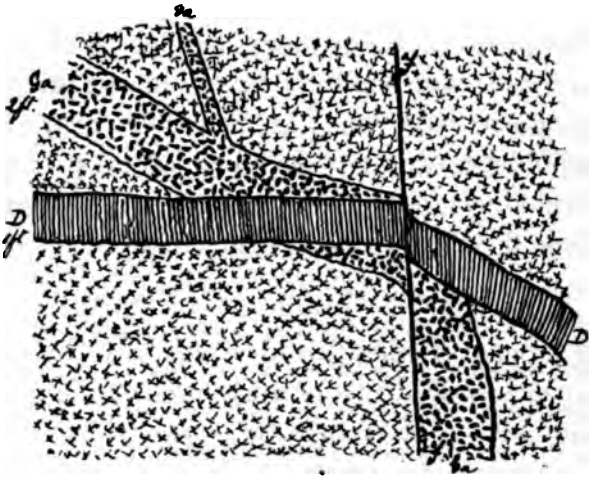


FIG. 9. DIORITE DYKE CUTTING GABBRO IN SERPENTINE. PORTH BEER.

But the most remarkable instances are those where the Diorite dykes cut the Gabbro mass. These are seen about the Manacles Point, and are in greatest evidence between there and Porthoustock. Here Gabbro and Diorite alternate in parallel processes in such regularity as to make doubtful without careful observation which is the intruder. In places the Diorite would appear to prevail, the dykes being so wide and near to each other. Some of the smaller are seen to thin out, and the Gabbro masses occasionally assume a lenticular outline. But that it is the Diorite which is the intruder may be inferred from the dykes cutting the Gabbro mass in other places, and by comparing the crystallisation at the junction planes. The great majority of the

Diorite dykes are nearly vertical, with a trend, roughly, north and south; they consequently cut the Gabbro dykes most frequently at angles approaching 90°. Still, there are instances where the Diorite and Gabbro take almost the same direction, as seen in Fig. 9, while near Lean Water dykes of the two kinds of rock may be seen running side by side through the Serpentine for some distance in actual contact.

THE BANDED SERIES OR GRANULITIC.

My study of the Lizard complex leads me to the conclusion that this peculiar rock forms the last of the series of magmatic upwellings in this volcanic area. In a former paper I have indicated a possible key to its origin that would account for its dual composition.[1] I gave there sufficient reasons for thinking it is intrusive in the Serpentine, so that it only remains to demonstrate its relation to the Gabbro and Diorite. In the first place, it is significant that no unmistakable instance of either of these rocks cutting the Granulitic can be found. Dealing with the simpler case first, the relation of the Diorite to the Granulitic, it must be noticed that Major-General McMahon makes mention of a Diorite dyke cutting the Granulitic at Polbarrow.[2] In respect to this re-

[1] A similar interpretation is suggested by Mr. Somervail in a paper on "The Schists of the Lizard District," *Geol. Mag.*, Decade III., vol. vii., 1890, p. 165, as an alternative to his "segregation" theory.

[2] *Quart. Journ. Geol. Soc.*, vol. xlv., 1889, p. 533. Mr. Somervail alludes to this alleged dyke in his paper before referred to, *Geol. Mag.*, 1890, p. 167.

puted dyke, I may say that I have three times sought for it, once in company with an experienced observer, but without success. The position is stated so definitely as to leave no possibility of mistaking the spot, and Diorite dykes are easily detected. No mention of such an instance is made by any other observer, so that one is obliged to conclude that the statement has been made in error; probably a basic band of the Granulitic being mistaken for a dyke. The description of a microscope section taken from this so-called dyke[1] also points by comparison to its being taken from a basic band of the Granulitic. Instead of the Diorite cutting the banded rock, the relation they bear to each other is seen in the section represented in the following Fig. 10 :—

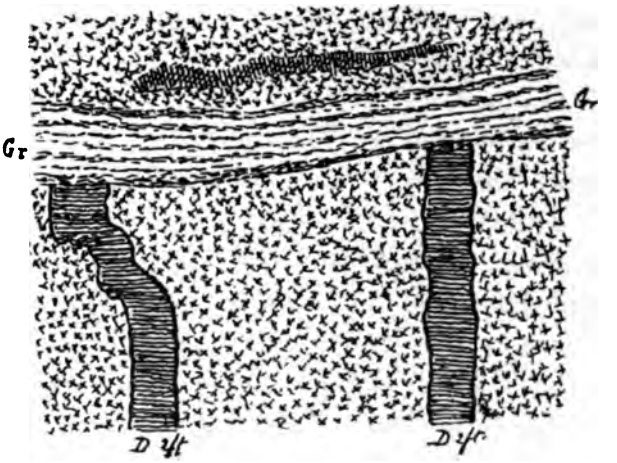


FIG. 10. GRANULITIC CUTTING DIORITE DYKES IN SERPENTINE. ENYS HEAD.

[1] *Quart. Journ Geol. Soc.*, 1889, p. 534.

Further evidence can be adduced by reference to that rounded mass of Diorite so conspicuous in the face of the cliff at Parn Voose. It has the appearance of, and is accepted by many observers as an inclusion in the Granulitic; and again, the noticeable Diorite dyke which cuts the Gabbro in the Serpentine under Kennack Cliff is cut by the tongue of Granulitic which runs up the cliff. It is, however, the relation of the Gabbro to the Granulitic that is most puzzling. For in numerous instances at Parn Voose and at Polbarrow they are seen to interpenetrate in a manner that saps one's preconceived notions of how a molten or semi-fluid magma would make its way through another presumably consolidated or partly so. Figures 11 and 12 represent typical instances out of the many to be met with, which if not absolutely contradictory, yet present very embarrassing evidence as to which rock is the intruder.

If, however, direct evidence in many cases is inconclusive, the conclusions to be obtained by inference are of quite a different character. There is no doubt about the Diorite cutting the Gabbro, and consequently following it in sequence, and as no Diorite dykes cut the Granulitic, the natural inference must be that the Granulitic got into its position after the Diorite, and must therefore be intrusive in the Gabbro. Moreover, there is direct evidence which strongly confirms the inference. There is a noticeable instance of an acidic dyke (it has been called Granite to distinguish it from the

Granulitic, there being no basic bands with it) which can be seen to cleanly cut the Gabbro at Lean Water. This was first noticed, and I believe

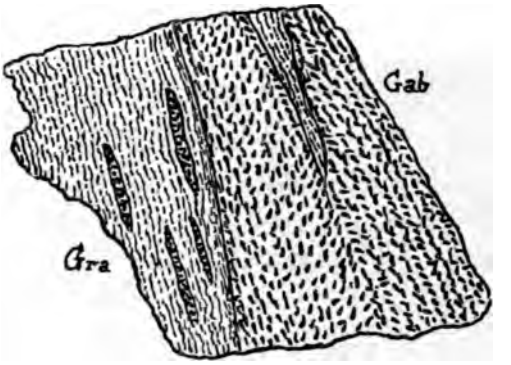


FIG. 11. BLOCK SHOWING GRANULITIC AND FOLIATED GABBRO. PARN VOOSE.

FIG. 12. BLOCK SHOWING VEINS OF GRANULITIC IN GABBRO. PARN VOOSE.

photographed, by Mr. Howard Fox. Now close examination shows this dyke to be an acidic band in connection with the Granulitic mass.

The following representation of a section, taken from the face of the cliff immediately north of Parn Voose beach, is eloquent in respect of the Granulitic as the intruding rock.

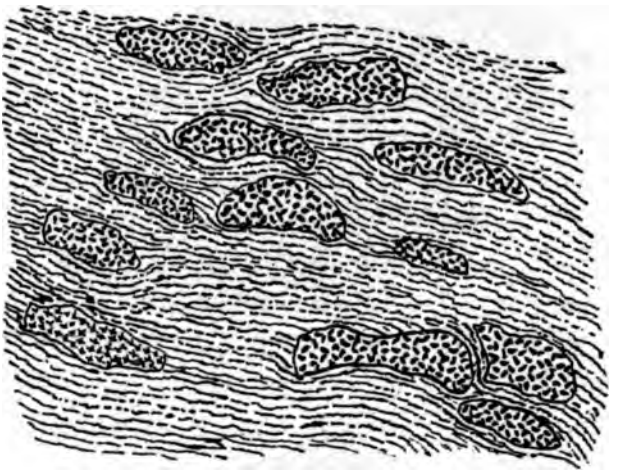


FIG. 13. GABBRO AND SERPENTINE IN GRANULITIC. FACE OF CLIFF NORTH OF PARN VOOSE.

I may, in addition, refer to the well-known instance of foliated Gabbro in the Granulitic at Parn Voose. It has been used as an illustration by both Professor Bonney and Mr. Teall. The view of Mr. Teall, that it is an included mass, is the generally accepted one, and it thus presents the strongest evidence in support of the Granulitic as a later protrusion. This mass of Gabbro is reached by the waves, which have worn round it and revealed a piece of Serpentine adhering to it. There is also another small inclusion to be seen at the beach level in the Granulitic of Kennack. It is nearly

white in colour and altered almost beyond recognition; but from its toughness and other similitudes there is little doubt it was originally a portion of the local Gabbro.

Considering the Granulitic as a single rock of dual composition, formed by the synchronous flow of two magmas, I am led by observation and inference to conclude that this rock is the solid result of the last plutonic upflow; thus terminating the sequence of igneous rocks formed in the area. There are many, however, who think that what is called the Granite of the area (being unmixed with the dioritic matter of the true Granulitic) is a flow of acidic magma, subsequent to and independent of the banded rock. I am disposed to think this is not the true interpretation of the phenomena; that its assumption is not necessary; and that there is wanting evidence to support it. The Granulitic is composed of bands of Diorite and Granite, which, near the planes of junction, have their minerals intermixed, which, however, is not the case within the bands. As intimated in a former paper, and in agreement with a point mentioned by Professor Bonney in this connection, it is probable that the acidic portion of the magma was of a more liquid consistency than its companion, and was in consequence more liable to be squeezed into thinner bands than the basic material, as well as into cracks and passages which the basic matter was too viscid to enter. Hence the fine granite veins found in the Hornblende Schist and Serpentine. At Parn

Voose, Lean Water, and other places, masses of this granite, without foliation lines in it, are found. It seems to me these owe their position and shape to the pouring of acidic material out of the complex magma, into spaces formed by the gaping of the rocks or where masses have been torn away by the intrusive material, the more mobile portion flowing freer into places where pressure was suddenly eased.

I have the authority of Messrs. Bonney and McMahon for assuming the synchronism of flow of the granite veins with the Granulitic. Now as there is identity of material in the granite and acidic folds of the banded rock, and as there are no veins of granite distinct from the acidic folds traversing the Granulitic, it seems to me not only simpler, but the view most in accordance with the appearances, that the so-called granite, instead of being a separate flow of most insignificant dimensions, should be considered as portions of the acidic material of the banded rock squeezed out of the intermixture of magmas as they came into contact with the solid rock that was being traversed by it.

The dykes through the cliff at Kennack have been the subject of considerable comment and theorising. Major-General McMahon gives a diagram[1] showing the first two as evidence of a separate upflow of granite material through the Granulitic. He considers the main branch of this

[1] *Quart. Journ. Geol. Soc.*, 1889, p. 540.

intrusion formed the second dyke, while a branch or rather thin sheet of the magma found its way up through the middle of a former Diorite dyke, both together constituting the No. 1 of the series.

Now the third and fourth dykes near to and parallel with these are admittedly Granulitic, and there are no indications of the first (although it is supposed to be the result of two subsequent intrusions) or the second, cutting the banded rock which lies very near in the direction of both dykes with no sign of displacement intervening. The want of evidence to support this view, together with a close observation and study of the Granulitic, leads me to think the granite to be a portion of this complex rock, and that together they form the last manifestation of plutonic action in the area. For it seems to me probable that this dual magma welled up with the declining force of dying volcanic action somewhere in a direction eastward (now sea-covered), possibly not reaching the surface at all. Creeping along through and under the former outpourings, it sent up tongues of varying constitution through the Serpentine, the more fluid acidic matter being occasionally squeezed out into veins and pockets. In its course it threw out processes varying in the proportions of its contrasted material, some of which extended far enough to appear now on the west of the peninsula. It would also appear that in some portions of its basic matter, richer in felspathic material,

porphyritic crystals had formed prior to its conjunction with the acidic magma; but as these are found only in the thick masses and folia of the Granulitic, it was probably a more viscid portion of the dioritic magma that contained them.

I humbly submit that the view enunciated respecting this banded rock and its constituents rationally interprets the observed phenomena in connection therewith, and furnishes a key to the following section which has been so long a geological puzzle.

That the whole complex of magmatic rocks herein considered is plutonic, formed at a considerable depth below the surface, may be inferred not only from crystallisation considerations, but from the presence in almost every microscopic section of tiny channels along which water, probably heated, circulated, and which are in most cases filled up by a deposit of pure Serpentine material.

In conclusion I may point out that the sequence of rocks herein set forth is in keeping with generalisations arrived at by several authorities on igneous effusions. Professor Gregory makes mention of a "general rule of ejection in the order of decreasing basicity."[1] Messrs. Dakyns and Teall, in a paper upon the igneous rocks of an area in Scotland,[2] state the first rocks formed were Peridotites, followed by Diorites, Tonalites, and Granites in the order of increasing acidity. And at the last

[1] *Quart. Journ. Geol. Soc.*, vol. 56, p. 219.
[2] *Quart. Journ. Geol. Soc.*, vol. 48, 1892, p. 104.

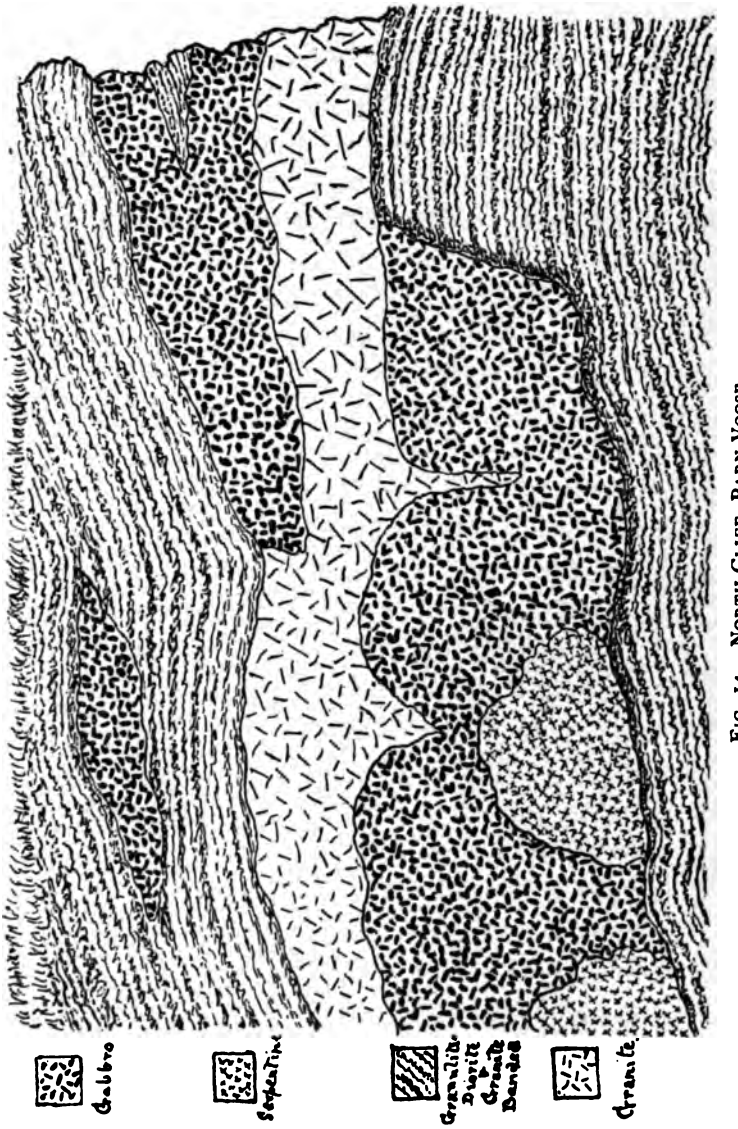
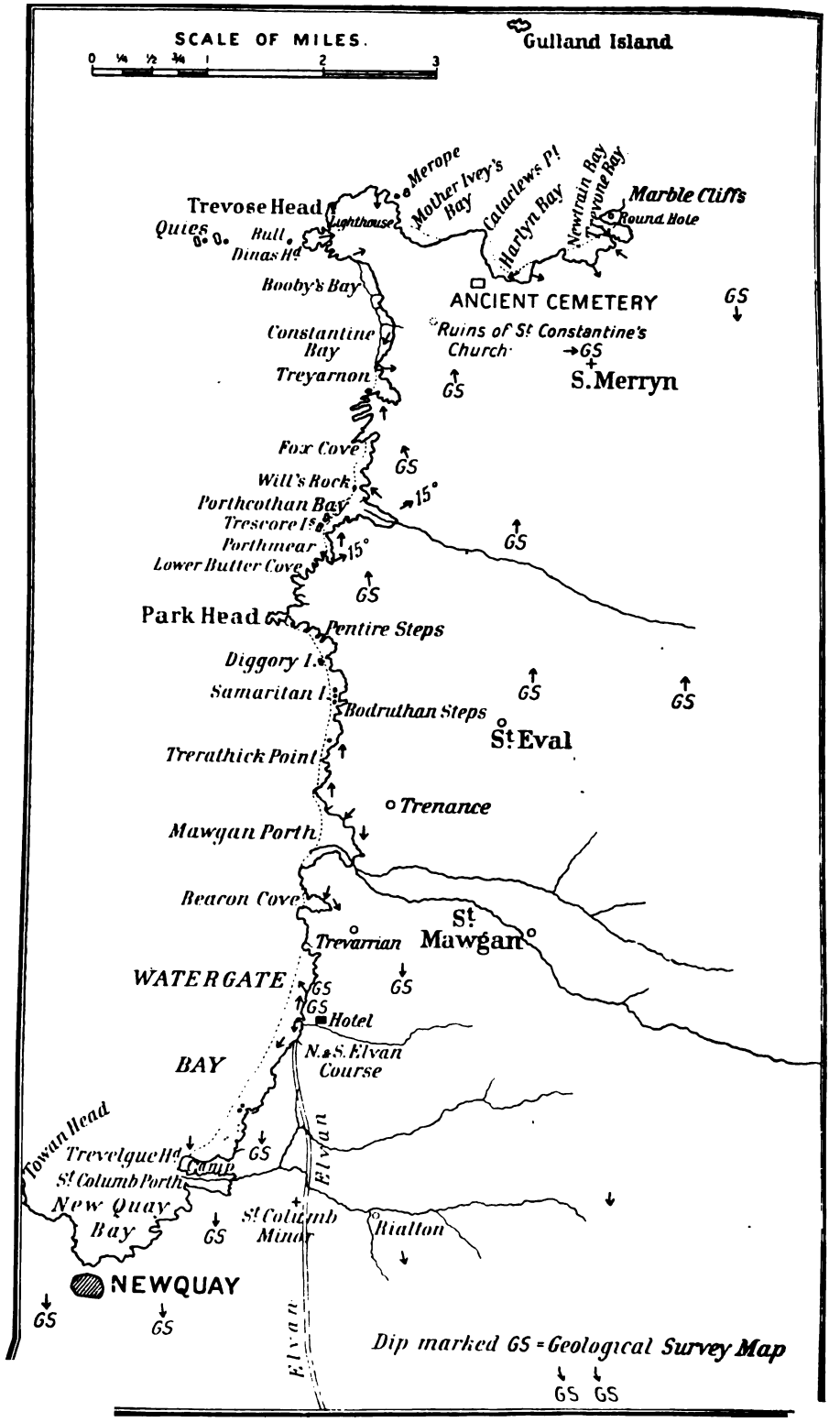


FIG. 14. NORTH CLIFF, PARN VOOSE.

meeting of the British Association at Glasgow, the President, Mr. J. Horne, F.R.S., in his address to Section C, refers to Mr. Harker as finding the plutonic phase of activity in Skye, confined to what is now the central mountain tract, to be represented by three groups of plutonic intrusions in the following order: Peridotites, Gabbros, and Granites.


SCALE OF MILES.
0 ¼ ½ ¾ 1 2 3
Gulland Island
Trevose Head
Lighthouse
Merope
Mother Ivey's Bay
Catherlews Pt
Harlyn Bay
Newtrain Bay
Trevone Bay
Marble Cliffs
Round Hole
Quies
Bull
Dinas Hd
Booby's Bay
ANCIENT CEMETERY
GS
Constantine Bay
Ruins of St Constantine's Church
GS
S. Merryn
Treyarnon
GS
Fox Cove
GS
Will's Rock
Porthcothan Bay
15°
Trescore Is
Porthmear
15°
GS
Lower Butter Cove
GS
Park Head
Pentire Steps
Diggory I.s
Samaritan I.
GS
GS
Bodruthan Steps
St Eval
Trerathick Point
Trenance
Mawgan Porth
Beacon Cove
St Mawgan
Trevarrian
WATERGATE
GS
GS
GS
Hotel
BAY
N. & S. Elvan Course
Towan Head
Trevelgue Hd
Camp
GS
Elvan
St Columb Porth
New Quay Bay
GS
St Columb Minor
Rialton
NEWQUAY
GS
GS
Elvan
Dip marked GS = Geological Survey Map
GS GS

ON THE DISTRIBUTION OF FOSSILS ON THE NORTH COAST OF CORNWALL SOUTH OF THE CAMEL.

By Howard Fox, F.G.S.

The eleventh volume of your *Transactions*, 1894, pp. 634–44, contains a description of some fossils occurring in the coast sections of the parishes of Padstow and St. Merryn. This was supplemented by a second paper in 1899,[1] which increased the list and extended the observations to the parishes south of St. Merryn, viz. St. Eval, St. Mawgan-in-Pyder, and St. Columb Minor.

During the past two years I have added a few new genera and localities to those already published, and for easier reference have drawn out tables of fossils mentioned by previous writers and of those found by myself, and made the annexed rough sketch of the district taken from the new one-inch ordnance map.

[1] "Geological Notes," vol. xii. part v. pp. 346–57.

Amongst the localities not previously mentioned are the following :—

BOATHOUSE COVE, TRESCORE.

South of Porthcothan we find a considerable range of beds with occasional fossils weathered out by the sea. In Boathouse Cove *Orthoceras*, *Petraia*, and *Conularia* appeared in better preservation than on many parts of the coast. The apparent dip of the beds is N.E. by E. at a low angle.

TRESCORE ISLANDS.

These islands contain fossiliferous beds, but the fossils are not in such good preservation as those on the mainland opposite, where *Petraia*, *Pleurodictyum*, *Crinoids*, etc., are fairly abundant. The rocks here appear to have a general southerly or south-easterly dip, with local reversals or disturbances.

BEDRUTHAN.

Under this head are classed the range of beaches south of Park Head and extending for more than a mile. The northern beach, "The Saddle," locally called Porth-an-Gaerde, is accessible at low water spring tides and exposes massive blue and green shales and slates, with occasional *Petraia*. Pentire Steps are the northern descent to this range of beaches. At the foot of the steps and adjoining cliff may be seen blocks and boulders of blue shale more or less fossiliferous, and *Petraia*, etc., are found in the cliff and foreshore *in situ*. Diggory

Island yielded some good specimens of *Pleurodictyum*. Samaritan Island further south, which is also left dry at low water, had some beds on the east side in which were numerous diminutive specimens of the new fossil, *Pteroconus mirus*, Hinde (*Nereitopsis*, Green), and similar forms were met with in some boulders and beds in the foreshore and mainland opposite. Some fifty specimens of this fossil, including fragments, were found in this district.

The southern descent to this range of beaches is Bedruthan Steps. The rocks at the foot of these steps afford the richest field for the fossil-seeker. Many beds are crowded with organic remains, unfortunately for the most part in very imperfect preservation. Blocks fallen from the cliffs and boulders in the sand yield some interesting specimens. The scour of the sand and the huge Atlantic rollers which break on this coast quickly weather out fresh specimens. So rapid is this process that in the depression or cup made two years ago by chiselling out the specimen of *Pteroconus* figured in your Plate 16, vol. xii., a new fossil was partially weathered out this year, and the block showing this feature is now in your museum. This special locality has yielded over one hundred specimens and fragments of *Pteroconus*.

Another specimen discovered at this locality was recognised by Dr. F. A. Bather, M.A., as a fragmentary starfish, and it is now in his hands for description.

BEACON COVE.

Half a mile south of Mawgan Porth a slate quarry was formerly worked in the cliff of Beacon Cove. The beds are almost horizontal; some dip slightly to south and east. A dubious specimen 14 inches in length occurred in this quarry; it suggested an *Orthoceras*, but the structure was insufficient to determine its origin. A few *Petraia* occur on the foreshore.

WATERGATE BAY.

Under this we class the range of beach and sand 2½ miles in length north of Trevelgue Head.[1]

ST. COLUMB PORTH.

In the cliff at Gravel Cove, inside a small island, there are beds of limestone crowded with organic remains. In the ascent from the large outer Camp Island to the Camp on the mainland there are limestone beds composed of imperfect fossils, described by previous observers.

[1] Since this paper was read I have found some fish remains in Watergate Bay, which were shown to Dr. A. Smith Woodward, F.R.S., who states that they are certainly Pteraspidian in character, and they may possibly belong to a new species; but more perfect specimens are required before they can be properly determined. In the surface ornamentation the ridges are closer, and they are more broken up into rows of tubercles than in *Pteraspis Cornubica*. The reticulation shown in certain portions of the specimens belongs to the median layer of the plates. I have placed these specimens in your Museum.

ST. COLUMB MINOR.

On the south side of the hill leading from Rialton Mill to St. Columb's Church are beds crowded with fossils, but so friable that no satisfactory identification of their species is possible.

NEWQUAY.

Here also, as recorded by previous observers, there are numerous friable beds containing organic remains.

SUMMARY.

The tables bring out some features of interest.

1. The Upper Devonian fossils, *Bactrites Budesheimensis* and *Cardiola retrostriata*, are not found south of Booby's Bay.

2. *Conularia* does not appear north of Booby's Bay nor south of Bedruthan.

3. *Pleurodictyum* does not appear north of Porthcothan nor south of Bedruthan.

4. *Pteroconus*, with the exception of a fragment probably exposed by a fold or fault at Lower Butter Cove, is confined to a single half-mile of the coast, of which Bedruthan Steps is the centre. From 150 to 200 specimens have been found here.

5. A Lower Devonian fossil, *Pteraspis Cornubica*, has not been found north of Bedruthan. I have found none north of Watergate Bay.

DIP.

With respect to the dip of the strata of this district little can be definitely determined. It is

not always easy to distinguish dip from cleavage, and the evidence of plication is so marked in certain sections that the apparent dip is in reality the inclination of the limbs of a fold. Speaking generally, the beds in the northern portion of this district have a northerly hade, while those in the southern portion, say south of Bedruthan, have a southerly hade; but there are numerous reversals, local disturbances, and faults innumerable.

TABLE No. 1.

	Reference.	Authority.	Permizen (Trewone).	Harlyn.	Bedruthan.	Trevarrion Quarry.	St. Columb Porth.	Newquay.
Corals	*Trans. R. G. C.*, vol. vii. p. 104	C. W. Peach	—	—	—	—	—	×
Turbinolopsis (Petraia) celtica	" " " " 49	S. R. Pattison	×	—	—	—	×	×
Favosites	" " " " 49, 50	"	—	—	—	—	×	×
Crinoidea	" " " " 48	"	×	×	×	—	×	—
"	" " " " 104	Peach	—	—	—	—	—	×
Trilobites	" " " " 104	"	—	—	—	—	—	×
"	" " " " 48	Pattison	—	—	×	—	—	—
Calymene	" " " " 49	"	—	—	—	—	×	—
Spirifera disjuncta	" " " " 49	"	—	—	—	—	×	×
" gigantea	" " " " 50	"	—	—	—	—	—	×
" sp.	" " " " 49	"	×	—	—	×	×	—
Orthis or Terebrabula	" " " " 50	"	—	—	—	—	—	×
Bivalve Lamellibranch	" " " " 48	"	—	—	×	—	—	—
Bellerophon trilobatus	" " vol. vi. " 82	Peach	—	—	—	—	×	—
	" " vol. vii. " 105							
Orthoceras ludense	" " " " 49	Pattison	×	—	—	—	×	—
Goniatites	" " " " 49	"	—	—	—	—	×	—
Onchus, portions of	" " vol. vi. " 82	Peach	—	—	—	—	×	×
	" " vol. vii. " 104, 105							
Coccosteus	" " vol. xii. " 350	W. Winwood	—	—	×	—	—	—
Steganodictyum (Pteraspis), 2 sp.	" " vol. vii. " 215, 391	Pengelly	—	—	×	—	—	—
	Trans. Devon. Association, 1868							

TABLE No. 2.

	Identified by	Shores of Camel.	Trevone Bay.	Newtrain Bay.	Harlyn Bay.	Mother Ivey's Bay.	Dinas Head.	Booby's Bay.	Constantine Bay.	Porthcothan.	Treascore.	Porth Mear.	Lower Butter Cove.	Bedruthan.	Mawgan Porth.	Beacon Cove.	Watergate Bay.	St. Columb Porth.	Newquay.
CŒLENTERATA.																			
Petraia celtica	Dr. Hinde, F.R.S.		×							×									
,, sp.	,,		×							×									
Zaphrentis calceoloides (?) sp.	,,			×				×						×					
Amplexus sp.	,,													×					
Camptophyllum sp. (?)	,,		×											×					
Lophophyllum sp. (?)	,,													×					
Pleurodictyum sp.	,,				×					×				×					
Michelinia	,,													×					
Favosites sp.	,,		×	×										×					
Alveolites sp.	,,													×					
Pachypora palmata	,,								×					×					
,, *reticulata*	Rev. G. F. Whidborne, M.A.													×					
,, sp.	Hinde		×					×						×					
Aulopora	,,													×					

ECHINODERMATA.																					
Sphærocrinus, Basal plate of cup similar to, Mid. Dev.	Dr. F. A. Bather, M.A.	—	—	—	—	—	—	—	—	—	—	—	—	×	—	—	—	—	—
Rhodocrinus or *Melocrinus*	„ „	—	—	—	—	—	—	—	—	—	—	—	—	×	—	—	—	—	—
Scaphiocrinus (?)	„ „	—	—	×	—	—	—	—	—	—	—	—	—	×	—	—	—	—	—
Acanthocrinus	„ „	—	—	—	—	—	—	—	—	—	—	—	—	×	—	—	—	—	—
Dicyclic crinoid cast of Anal tube	„ „	—	—	—	—	—	—	—	—	—	—	—	—	×	—	—	—	—	—
Crinoidal fragments	„ „	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
Starfish fragmentary not yet described	„ „	—	—	—	—	—	—	—	—	—	—	—	—	×	—	—	—	—	—
ANNULOSA.																					
Serpulites (?)	Hinde	—	—	—	—	—	—	—	—	—	—	—	—	×	—	—	—	—	—
TRILOBITA.																					
Phacops (*Trimerocephalus*) *lævis*	„	—	×	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
„ sp.	„	—	×	—	—	—	—	×	—	×	—	—	—	×	—	—	—	—	—
POLYZOA.																					
Polypora ripisteria	Whidborne	—	—	—	—	—	—	—	—	—	—	—	—	×	—	—	—	—	—
Fistulipora sp.	Hinde	—	—	—	—	—	—	—	—	—	—	—	—	×	—	—	—	—	—
Monticuliporoid, fragment of	„	—	—	—	—	—	—	—	—	—	—	—	—	×	—	—	—	—	—
Retepora sp.	„	—	—	—	—	—	—	—	—	—	—	—	—	×	—	—	—	—	—
BRACHIOPODA.																					
Chonetes sp.	R. B. Newton, F.G.S.	—	—	—	—	—	—	—	—	—	—	—	—	×	—	—	—	—	—
Orthis arcuata, Phill.	Whidborne	—	—	—	—	—	—	—	—	—	—	—	—	×	—	—	—	—	—
Spirifera sp.	„	—	—	—	—	—	—	—	—	—	—	—	—	×	—	—	—	—	—
Centronella or *Cryptonella*	Newton	—	×	—	—	×	—	—	—	—	—	—	—	—	—	—	—	—	—
Brachiopods, indeterminate	„	—	×	—	—	—	—	×	—	—	—	—	—	×	—	—	—	—	—

TABLE No. 2 (*continued*).

	Identified by	Shores of Camel.	Trevone Bay.	Newtrain Bay.	Harlyn Bay.	Mother Ivey's Bay.	Dinas Head.	Booby's Bay.	Constantine Bay.	Porthcothan.	Trescore.	Porth Mear.	Lower Butter Cove.	Bedruthan.	Mawgan Porth.	Beacon Cove.	Watergate Bay.	St. Columb Porth.	Newquay.
LAMELLIBRANCHIATA.																			
Cardiola retrostriata (Cardium palmatum)	Newton	—	×	—	—	—	—	×	—	—	—	—	—	—	—	—	—	—	—
Forms not determinable	„	—	×	—	—	—	—	×	—	—	—	—	—	×	—	×	—	—	×
GASTROPODA.																			
Murchisonia sp.	„	—	—	—	—	—	—	—	—	—	—	—	—	×	—	—	—	—	—
Euomphalus sp.	„	—	×	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Loxonema sp.	Whidborne	—	—	—	—	—	—	—	—	—	—	—	—	×	—	—	—	—	—
PTEROPODA.																			
Styliola sp.	T. Rupert Jones, F.R.S.	—	×	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Hyolithes	Hinde	—	—	—	—	×	—	—	—	—	—	—	—	—	—	—	—	—	—
Pteroconus mirus (*Nereitopsis*, Green)	„	—	—	—	—	—	—	—	—	—	—	—	×	×	—	—	—	—	—
Tentaculites	„	—	×	—	—	×	—	×	—	—	—	—	—	—	—	—	—	—	—
Conularia	„	—	—	—	—	—	—	×	×	×	×	—	×	—	—	—	—	—	—
CEPHALOPODA.																			
Orthoceras cochleiferum, allied to	G. C. Crick, F.G.S.	—	—	—	—	—	—	×	—	—	—	—	—	×	—	—	—	—	—
„ sp.	„ „	—	×	—	—	—	—	×	—	×	×	×	—	—	—	—	—	—	—
Bactrites Budesheimensis	„ „	—	×	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
„ sp.	„ „	—	×	—	—	—	—	×	—	—	—	—	—	—	—	—	—	—	—

Goniatites (*Anarcestes*) *Noeggerathi* . . .	„ „ .	—	—	—	—	—	—	×	—	—	—	—	—	—	—	—	—	—	—
Goniatites (*Tornoceras*) simplex	„ „ .	—	×	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
„ *retrorsus umbilicatus* syn *globosus* (?) .	„ „ .	—	×	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
„ sp. . . .	„ „ .	—	×	—	—	×	—	—	—	×	—	—	—	—	—	—	—	—	—
Anarcestes c/f *latiseptatus* (?) .	„ „ .	—	×	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
„ sp. . . .	„ „ .	—	×	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Tornoceras globosus . .	„ „ .	—	×	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
„ sp. . . .	„ „ .	—	×	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Mimoceras compressus . .	„ „ .	—	×	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
„ sp. . . .	„ „ .	—	×	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Agoniatites transitorius (?) .	„ „ .	—	×	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
VERTEBRATA.																			
PISCES.																			
Pteraspis Cornubica . . .	Dr. Smith Woodward, F.R.S.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×	—	—
„ sp.	„ „	—	—	—	—	—	—	—	—	—	—	—	—	×	—	—	×	—	—
Scaphaspis sp. . . .	„ „	—	—	—	—	—	—	—	—	—	—	—	—	×	—	—	—	—	—
Phlyctænaspis acadica (?), Lower Devonian . . .	„ „	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	×	—	—
Climatius sp., fragment of spine allied to . . .	„ „	—	—	—	—	—	—	—	—	—	—	—	—	×	—	—	—	—	—
Ganoid, fragment not yet described . . .	„ „	—	×	—	—	—	—	—	—	—	—	—	—	×	—	—	—	—	—
ALGÆ.																			
Fucoids (?) . . .	Hinde . . .	—	×	—	—	—	—	—	—	—	—	—	—	×	—	—	—	—	—

THE PLUTONIC AND OTHER INTRUSIVE ROCKS OF WEST CORNWALL IN THEIR RELATION TO THE MINERAL ORES.

By J. B. HILL, Esq., R.N.

(H.M. Geological Survey.)

(Communicated by the permission of the Director of the Geological Survey.)

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INTRODUCTORY.

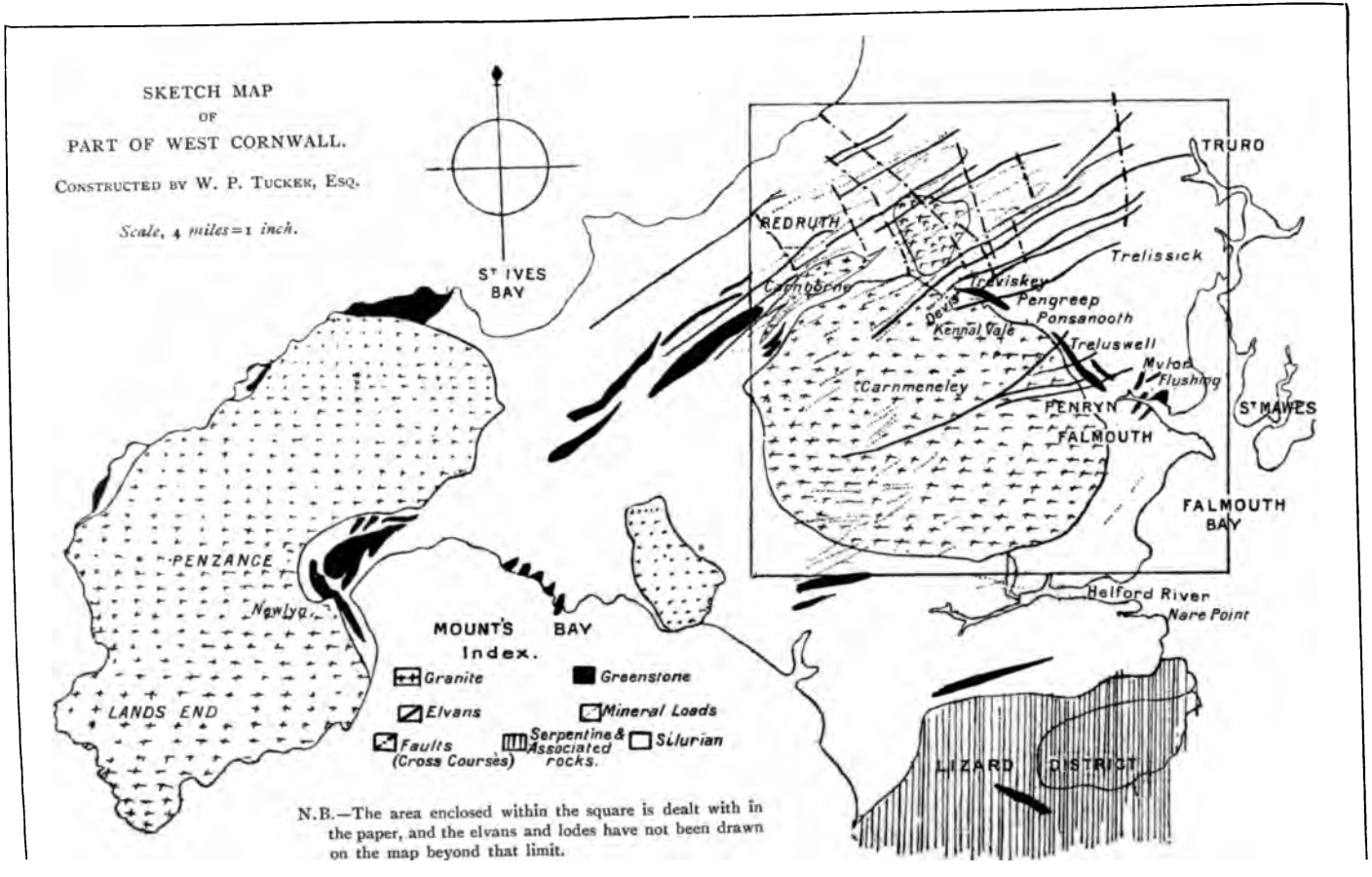
At the last Annual Meeting of this Society I took as the subject of my paper the investigation of geological structure in West Cornwall, dealing more particularly with the region lying approximately between Falmouth Bay and the mining district of Camborne. On that occasion I discussed the structures that were displayed by the Palæozoic sediments, and submitted evidence of the vast amount of mechanical deformation to which the latter have been subjected by the operation of powerful earth stresses, which have so masked their original character that the evidence afforded by the dip of the strata can no longer be depended upon as a reliable index of stratigraphical relationship. I pointed out to you that not until the geological structure of the area was clearly understood should we be in a position to attack the problem of the metalliferous lodes with any hope of success. I propose to-day to offer some remarks on the structures of the granite and its allied rocks of the same region, which together with those

Palæozoic sediments contain the mineral ores. We shall then be in a position to judge how far these structures throw light on the phenomena of the lodes, and to what extent such knowledge can be applied in their systematic investigation.

THE CARN MENELEZ GRANITE.

The granites of the West of England were described by De la Beche in his great memoir on the Geology of Cornwall, Devon, and West Somerset. In that report he referred to the large mass lying between Penryn and Camborne as the Carn Menelez granite; and as Mr. Teall, in his *British Petrography*, and other writers have repeated De la Beche's nomenclature, it will be convenient to continue this designation for that granite intrusion which is such a dominant feature in the region to which this paper more particularly refers.

The conclusions of De la Beche, who formed the opinion that the various granite masses extending from Dartmoor to the Land's End were intimately related and of one geological age, have been confirmed by subsequent observers. Their affinities to one another, and to the elvan dykes with which they are associated, are so marked as to leave us no alternative but to conclude that both granites and dykes belong to one petrographical province.


SKETCH MAP
OF
PART OF WEST CORNWALL.
CONSTRUCTED BY W. P. TUCKER, ESQ.
Scale, 4 miles=1 inch.
ST IVES BAY
REDRUTH
Carnborne
TRURO
Trelissick
Treviskey
Pengreep
Ponsanooth
Kennal Vale
Treluswell
Mylor
Flushing
Carnmeneley
PENRYN
FALMOUTH
ST MAWES
FALMOUTH BAY
PENZANCE
Newlyn
MOUNT'S BAY
Helford River
Nare Point
Index.
Granite
Greenstone
Elvans
Mineral Loads
Faults (Cross Courses)
Serpentine & Associated rocks.
Silurian
LANDS END
LIZARD DISTRICT
N.B.—The area enclosed within the square is dealt with in the paper, and the elvans and lodes have not been drawn on the map beyond that limit.

LITHOLOGICAL CHARACTERS OF THE GRANITE.

This mass may be described as a grey, acid, coarse-textured granite consisting of orthoclase and plagioclase, abundant quartz, and both white and black mica, together with tourmaline in varying proportions. Lithia mica is a common constituent in parts of this granite.[1] Porphyritic felspars are commonly distributed, and include individuals of idiomorphic orthoclase exhibiting twinning of the Carlsbad type. Although not so coarsely crystalline as some of the other Cornish granites, which contain porphyritic felspars of large size, like those of the Land's End type or of the mass near St. Austell, yet the Carn Menelez rock presents a texture which, as compared with other British granites, is not only coarse as regards the matrix, but also in the size of its porphyritic felspars, which are often 2 or 3 inches in length. Although both muscovite and biotite are usually present, every variation may be observed in their relative abundance. In some sections muscovite may occur almost to the exclusion of the biotite, while in others the mica may be almost entirely of the latter variety. Tourmaline occurs

[1] The following analysis of the Carn Menelez granite, by Mr. Philips, is taken from Teall's *British Petrography*, page 314. The locality selected is Carn Brea Hill, near Redruth, and represents a small outlier close to the Carn Menelez mass.

SiO_2 . . 74·69	MnO . . 0·58	Na_2O . . 1·18
Al_2O . . 16·21	CaO . . 0 28	Li_2O . . 0·10
Fe_2O_3 . 1·16	MgO . . 0·48	H_2O . . 1·23
FeO . . Trace	K_2O . . 3·64	99·55

Specific gravity . . 2·64.

both as a constituent of the ground mass, in which it generally takes the form of stumpy prisms, and as a later introduction coating the faces of joint planes in needle-shaped crystals which tend to dispose themselves in bunches. These needles sometimes attain a length of 2 or 3 inches. Tourmaline seems to be a conspicuous mineral in the more acid portions of the granite which vein the normal type. In some veins of coarse acid granite tourmaline occurs to the exclusion of biotite, and some of the individuals have been noticed under these conditions as large as half an inch. Where such coarse acid veins have been observed to contain tourmaline as well as massive schorl, contiguous veins which are finer in texture are found to be rich in biotite, while tourmaline is then entirely absent. In the coarse veins containing tourmaline the mica that occurs is muscovite. Other instances have been observed where the only mica contained in the coarse acid veins is a white mica.

In that part of the Carn Menelez granite which has yet been mapped no perceptible change of texture has been noticed at its outer edges. It should be mentioned, however, that sections showing actual junctions of this rock with the slate are rare; yet, if the mass be regarded as a whole, a distinct difference of texture may be detected in it; the marginal parts, which, broadly speaking, are finer grained than the interior, contain a larger proportion of biotite, frequently to the almost entire exclusion of white mica, and are

heavier than the coarser-grained material — so much so as to affect its commercial value. This increase of specific gravity (about 1 per cent.) is no doubt due to differentiation in the mass prior to consolidation by the concentration of the basic oxides (ferro-magnesian) to the cooler peripheral portions.

Although the junction of the granite with the slates can be rarely seen, the contact metamorphism of the latter may be sufficiently studied. As the scope of this paper does not admit of a detailed description of these phenomena, it will be sufficient to state that it presents an aureole of "knotted" slate, the innermost portions of which are crowded with minute scales of muscovite and biotite, while near the junction andalusite is abundant. The phenomena thus differ considerably from those displayed by the Land's End granite, near to which the sedimentary rocks are indurated and change into hornfels to such an extent that it is often difficult to distinguish these rocks from the greenstones. The metamorphic aureole of the Carn Menelez granite so far examined appears to be limited to a distance of 1,000 yards, whereas that of the Land's End granite considerably exceeds this—a fact which is in agreement with the more advanced state of metamorphism of the latter.

STRUCTURES OF THE GRANITE—JOINTS.

The comparative uniformity in the direction of the major joints in the granite over the whole

Cornish area was long ago pointed out by De la Beche. In the Carn Menelez granite one set of vertical joints, having a prevalent direction of N.N.W., is crossed by another vertical set at right angles. These two systems, in conjunction with a third set more or less horizontal, divide the whole rock into a set of roughly prismatic segments. The great regularity of these joint planes has been an important factor in the rapid development of the granite industry of Cornwall, as compared with other localities in Britain. The joints have received local names. Those which trend N.N.W. are known as *cleaving-way* joints, those at right angles are the *tough-way* joints, while the horizontal joints are known as *floors* or *quartering-way* joints. The grain of the granite has been found to correspond with the position of the joints, hence their names.

The *tough-way* joints, or those which correspond roughly to an E.N.E. direction, may sometimes be faults, instances being common where the horizontal *floors* have been thrown by them as much as 2 feet, or where the joints display slickensided surfaces indicative of relative displacement of the walls. Further, the finer-grained aplite veins tend to take a course parallel to these same joints, while the elvan dykes undoubtedly follow the same parallelism.

The horizontal joints or *floors* form one of the most characteristic features as seen in the field. De la Beche considered them as original structures

and not as produced at a comparatively late period by the decomposition of the outer crust. The fact that these horizontal joints have been faulted by the *tough-way* joints proves them to be at least older than these lines of division. Later joints, however, occur which cannot always be distinguished from the true *floors* into which they appear to merge. The intervals between these horizontal joints or *floors* increase with depth from the surface. In one of the quarries the joints are 60 feet apart, while in another they are so favourably disposed that blocks of stone can be produced 120 feet long, 28 feet wide, and 30 feet deep.

The elvans display considerable irregularity in their jointing. One of these dykes, intruded along the *tough-way* of the granite, has a common *quartering-way* joint with that mass, while one of its dominant joints corresponds with the *cleaving-way* joints of the granite.

CLEAVAGE OF THE GRANITE.

The rock cleaves most readily along planes parallel to the *floors* or horizontal joints. The next easiest cleaving plane is that parallel to the *cleaving-way* joints, while the rock cleaves most irregularly parallel to the *tough-way* joints. This rule is understood to hold good over the whole granite area. An examination of numerous sections in which all three types of jointing are visible appears to show a distinct tendency to orientation along planes parallel to the horizontal *floors* and

to the *cleaving-way* joints, although no absolute regularity in this respect has been observed. While in many instances these joints trend away from the normal direction, it is unusual to find more than one joint deflected in the same exposure. The greatest irregularities in the jointing and corresponding cleavage occur in the vicinity of the aplite veins. The horizontal joints, although often undulating, are the most regular of all. The cleaving planes of the rock are not always strictly parallel to the joints, yet, on the whole, the marked parallelism between the joints and the directions along which the rock most readily cleaves is unmistakable. From the evidence of a large number of sections there is reason to conclude that not only is there a close connection between the major joints and the grain of the rock, but that this grain is dependent on the internal mineral arrangement of the granite, and that all three phenomena are closely related. The uniformity in these structural features appears to be diffused over the entire granite mass, and common to the whole of the granites of the West of England. The internal crystalline arrangement appears to consist first in a tendency for the mica to lie with its basal planes horizontal; secondly, in a disposition of the felspars, both as constituents of the matrix and as porphyritic individuals, to rest with their flat sides in a similar position; and thirdly, in the orientation of the felspars with their long axes parallel to the *cleaving-way* joints. The first and second of these

structures probably explain the proneness to cleave parallel to the horizontal joints,[1] while the third seems to show why the rock tends to cleave in planes parallel to the cleaving-way joints. The rock, however, presents no structures so defined as those of foliated rocks.[2] It does not differ to any marked degree in outward appearance from ordinary granite. Yet it has evidently undergone a rude and initial stage of foliation, whereby its component minerals have been forced to rearrange themselves in a definite direction so as to acquire a cleavage.

UNIFORMITY OF GRANITE STRUCTURES IN WEST OF ENGLAND.

My own investigation of the structures displayed by the West of England granites is confined to the Carn Menelez mass, but the researches of De la Beche make it clear that the great divisional planes to which I have drawn attention are common to all the granite masses from Dartmoor to the Land's End, and that they follow a common direction. And I am informed by Mr. J. A. Freeman[3] that not only is this the case as regards the joints, but that the grain of the rock in the different granites preserves a corresponding relation to those joints just as it

[1] This arrangement may be regarded as the result of the tendency to acquire a horizontal position due to the force of gravitation.

[2] Some exceptional foliation in its marginal phases is described later.

[3] A member of the largest firm connected with the granite industry in the West of England, whose quarries are distributed all over Cornwall.

does in the Carn Menelez mass. As I have shown the grain to be the result of mineral orientation in the latter region, it follows that the West of England granites possess not only a common system of jointing, but a common crystalline orientation.

EXPLANATION OF THE ORIENTATION.

We have seen that these granite masses in the West of England have been intruded amongst sediments that have been profoundly affected by earth movements. Although in Cornwall they cut rocks probably of Silurian age, in the eastern part of the area in Devonshire they pierce rocks of Culm Measure age. These movements had ceased before the accumulation of the Triassic deposits, which contain pebbles of the granite and of the deformed sediments. It has been inferred, therefore, that the granite irruptions mark the final stage of the epoch with which those movements are connected. In other words, it is probable that the deformation of the sediments and the irruption of the granite owe their origin to a common cause.

FOLIATED GRANITES OF ARGYLLSHIRE.

In my investigations of the metamorphic rocks of Argyllshire, in the neighbourhood of Loch Awe, "I had reason to suspect, that in connection with the intense progressive metamorphism that occurs in the area lying between the granite masses of Glen Fyne and Ben Cruachan, the intense regional type of metamorphism was linked with the same

phenomena as those that afterwards resulted in the irruption of the granite masses."[1] In other words, I regarded the granites of Ben Cruachan and Glen Fyne as marking the final phase of the Highland movements in that region.

While engaged on the survey of the Ben Cruachan granite and its metamorphic aureole, although I observed a rudely orientated structure in parts of that granite, I did not pursue my investigations so far as to study its relationship with the joint planes of that mass. Indeed, only a small portion of the area, confined to its south-eastern margin, was mapped by myself. The survey of that region was continued by my colleague Mr. H. Kynaston, who has furnished most interesting contributions to the petrology of this plutonic complex and its contact metamorphism on the rocks at its margin, which are well worth the study of those interested in these phenomena.[2] Mr. Kynaston has observed in the Moor of Rannoch area a foliation in the granite indicated by the arrangement of the hornblende and biotite. This foliation, which is visible in a hand specimen, is scarcely perceptible under the microscope. He notes that the planes of foliation in the older schists coincide with the general trend of the plutonic belt, and that the planes of foliation observed in part of the Moor of Rannoch granite follow similar lines.

[1] *Quart. Journ. Geol. Soc.*, vol. lv. p. 491.

[2] Mr. Kynaston's observations are published in the *Summary of Progress of the Geological Survey*, 1897, 1898, 1899, and 1900.

FOLIATED GRANITES OF SOUTH OF SCOTLAND.

Moreover, if we turn to the Southern Uplands of Scotland, my colleagues Messrs. Peach, Horne, and Teall describe granite intrusions succeeding stresses which have powerfully affected Silurian rocks. These granite masses pierce Upper Silurian strata, and are older than the Upper Old Red Sandstone which are partly made up of its detritus. In one instance the granite is foliated along the margin of the mass, a structure which is evidently due to dynamic movement, for the massive granite, together with the later acid veins, have been foliated in one common direction. Mr. Teall considers it highly probable that the pressure producing this foliation "acted before the rock mass had actually cooled."[1]

RELATION OF GRANITE TO EARTH MOVEMENTS.

We may regard, likewise, the West of England granites as bearing an analogous relation to the post-carboniferous earth movements of the region. This view finds considerable support in the evidence that I will now lay before you.

In my paper communicated to this Society at its last meeting[2] I indicated that "although the strata have a general dip to the south-east between

[1] See my previous paper, read before this Society in November, 1898, "The Lower Palæozoic Rocks of the South of Scotland, viewed in connection with the Lower Palæozoic Rocks of Cornwall," p. 19; and Geological Survey memoir on the Silurian rocks of Scotland, by Messrs. Peach, Horne, and Teall.

[2] "On Some Geological Structures in West Cornwall," *Trans. Royal Geol. Soc. Cornwall*, vol. xii. part 6, 1901.

Falmouth and Truro, and we are apparently crossing the strike from the coast to the heart of the county, yet instead of getting deeper in the stratigraphical series we are on precisely the same geological horizon at Truro as at Falmouth, the intervening ground being made up of a succession of isoclinal folds." That is to say, the apparent downward succession of the beds is an illusion brought about by the inversion of the isoclinal folds into which they have been thrown.

Now, from a large series of observations over these slates I have found that the cleavage is oblique to the bedding, and while the latter has an average south-easterly dip, the hade of the former is about S.S.E.; that is to say, the pressure which brought about these movements acted along a direction of N.N.W. and S.S.E. Judging from the data furnished by that part of Cornwall situated between Truro and Gerrans Bay, there are grounds for believing that the rocks owe their deformation to lateral movements from S.S.E. to N.N.W. But for my present purpose this point is immaterial; it will be sufficient to demonstrate that the stresses acted along a direction from S.S.E. to N.N.W. without insisting from which of these points they emanated.

It will be immediately seen that this direction agrees with the orientation of the granite which is related to the "*cleaving-way*" of that rock. This coincidence is too remarkable to be explained by any other argument than that based on uni-

formity of cause. We have strong reasons, therefore, for assuming that the granite irruptions and the earth movements are not only closely related, but that the latter had not ceased to operate before the final solidification of the former.

FOLIATED GRANITE NEAR PENRYN.

This reasoning finds support from the evidence of two foliated granitic sills that flank the granite margin at Treluswell, near Penryn. In the cutting adjoining the railway arch two sills are interposed between the slates and participate in the stresses to which they have been subjected. They are about thirty yards distant from the granite junction, and share in the hade of the slates which dip away from the granite. Their foliation planes correspond with the cleavage planes of the slate between which they are intercalated. Microscopic examination (3,364)[1] shows them to be granite, and to be allied to that rock rather than to the elvan dykes to which their mode of occurrence would otherwise suggest their correlation. Their N.N.W. direction, moreover, parallel to the granite boundary is nearly at right angles to the course of the elvan dykes of the district. The evidence suggests their modification by pressure before final consolidation, a conclusion borne out by their field behaviour, which points to interfolding with the slates as the explanation of the repeated intercalation which

[1] The figures within brackets used in this paper refer to the micro-slides in the Geological Survey collection.

marks their upper junctions. The igneous intercalations, however, retain no evidence of such folding as would have been the case had the rock been solid at the time of its deformation.[1] There is, unfortunately, no available section of the granite mass adjoining, so that the nature of its margin at this locality cannot be investigated.

FOLIATED GRANITE NEAR PONSANOOTH.

When we follow the granite, however, to Ponsanooth, about one and a half miles N.N.W. of Treluswell, we find the granite very distinctly orientated for about half a mile from its margin. Proceeding up the valley at Kennal Vale, this orientation is markedly conspicuous with a strike of about N.N.W., agreeing with the corresponding strike of the foliation planes of the granite sills at Treluswell. Moreover, the direction of the orientation at both localities coincides with that to which attention has already been drawn as being parallel to the *cleaving-way* joints over the whole area. At Kennal Vale, however, these phenomena are carried a step further. Over the district generally the orientation is so feeble that it would often escape observation if not specially sought for. Moreover, although there is a general uniformity in the direction of orientation, it is by

[1] It is of course possible that the irregular junction of the sills and slate may represent the original intrusion, and that the foliation of the former may have been induced after solidification, but microscopic examination of the section suggests to me pressure before final consolidation.

no means constant, and if examination was confined to a limited number of sections the results obtained might be misleading. At Kennal Vale, however, the parallelism is so marked that it could not fail to be detected by the most cursory examination, and it approaches a definite structure. So much so, that the orientation is no longer the feeble approach to crystalline arrangement confined to the attempt at parallelism of a sufficient number of the elongated minerals (porphyritic felspars) to ensure a grain, but there are definite visible planes set up in the rock which dip steeply towards the margin of the granite, and the rock is sometimes so foliated that its schistose character can be detected in a hand specimen.

The foliation of the granite at Kennal Vale agrees in its trend and general hade with the corresponding planes in the slates which flank its margin.

STRUCTURES OF GRANITE AS A TEST OF GEOLOGICAL AGE.

We have seen, therefore, that the Carn Menelez granite is divided by the structural planes common to all rocks, viz. joints. These joints have a uniform direction, not only over the entire plutonic mass, but extend beyond its own limits, and are common to the whole of the post-carboniferous granites of the West of England. We have likewise seen that the grain of the rock is related to the directions of these joints. And, finally, that

the grain coincides with, and is probably the result of, a crystalline orientation. This orientation, though of an obscure nature, is sufficiently constant to determine a grain that is uniform over the whole region. While our knowledge of the genesis of these plutonic masses is of the most limited kind, we may probably safely conclude that their irruption coincides with regions of stress. Applying this hypothesis to the Carn Menelez granite, I have endeavoured to trace a connection between these latter phenomena by means of the planes of orientation. If I am correct in the conclusions I have formed, they must necessarily have an important bearing on the investigation of other regions, as by these means it may be possible for us to determine the geological age of granites where other methods are unavailing. When we realise that these structures are common in the West of England to a series of granite intrusions extending over a distance of at least 130 miles, it will be understood how far-reaching the application of such methods may be for the correlation of plutonic masses over widely separated areas.

MICA TRAPS.

Besides the granites and elvan dykes we find other igneous rocks in the district, most of which have been referred to by previous writers as greenstone. They are of greater antiquity than the granites and elvans, and have been variously modified by deformation and contact metamor-

phism. In addition to these greenstones we have mica traps which, notwithstanding their advanced stage of decomposition, have suffered very little mechanical deformation apart from fault dislocation. While of later age than the bulk of the so-called greenstones, they appear to have been more affected by crust movements than the elvan dykes. Mr. J. A. Philips evidently included these rocks with the elvans; whilst, on the other hand, Mr. Collins has included amongst the mica traps rocks which more properly find their place in the greenstone series.

It may be remarked that all the greenstone bands so far mapped in the district are found in the Mylor series,[1] and that both the bands which will be described occur in the aureole of contact alteration which encircles the granite mass, and to which allusion will be made later. While greenstones are associated with the Mylor series, the Portscatho division contains within its limits an assemblage of mica traps, which have marked resemblances in the field to the lamprophyres that occur amongst the schists of the Scottish Highlands. They have been noted exceptionally in the Falmouth series, and one is seen to pierce the Nare Point conglomerate.

MICA TRAPS—LITHOLOGICAL CHARACTERS.

Although these mica traps are everywhere in a highly decomposed condition, they are markedly

[1] The sedimentary divisions were described in my former paper, *Trans. Royal Geol. Soc. Cornwall*, vol. xii. part 6, 1901.

different from the greenstones. Nothing in their appearance suggests metamorphism. The type of alteration which they have undergone is rather that of decomposition under atmospheric influences. These rocks present a rusty-brown aspect in the field, and are so weathered that fresh specimens are obtained with difficulty. They occur as sills and dykes among the slates, on which they have effected a limited amount of contact alteration, confined to indurating and sometimes converting them into hornfels to a distance of six or nine inches from the edge. The same mass which lies between the strata as a sill may suddenly divert its course and behave as a dyke, and small veins have been discharged from them into the adjoining strata. They vary from a foot in width to fifty yards. In many instances spheroidal weathering may be observed among them, cores of more solid rock being encircled by concentric outer layers of exfoliating material. Flow-structure is not uncommon, being especially noticed in the finer-grained marginal portions. In some rocks exhibiting flow-structure the spheroidal cores are elongated in the direction of the flow, while rounded inclusions of quartz may be seen with their long axes in a corresponding position. Notwithstanding their advanced state of decomposition, the ground mass of these rocks can generally be seen to consist of a medium-grained admixture of biotite and felspar, while inclusions of quartz and crystalline felspathic rock are characteristic.

Inclusions of slate are also frequently seen. The quartz and felspar inclusions vary considerably both in size and shape. The quartz has been observed in masses as large as nine inches, which grade downwards to the smallest dimensions. The inclusions, both of quartz and felspar, have often been perfectly rounded, while in other cases they have a brecciated appearance. Sometimes both these minerals occur in perfectly rectangular fragments. These rocks vary considerably in their texture, some being as coarse as large-grained dolerites, while others assume the texture of basalt. The mica traps probably vary in acidity; in some the undecomposed cores seem to be made up altogether of felspar. In one of them, which is deeply weathered and contains these acid cores, the mica is white, probably due to bleaching. Although quartz is so prominent as included individuals, it does not appear to enter largely into the composition of the matrix. In the largest and coarsest sill, although the texture of the rock is fine towards the margin, the biotite crystals retain their normal dimensions. In this area the mica traps appear to be confined to the minette family of that group.

STRUCTURES OF THE MICA TRAPS.

These minettes would appear to have been intruded after the slates had been cleft, but before the cessation of the stresses, which have acted on a part of the crust sufficiently within the zone of fracture that, instead of the strains finding relief

in a system of fissures more or less divided, the mass has been everywhere free to give way, so that the entire crust is minutely fractured and converted on a large scale to what may be termed a regional breccia. Consequently these rocks occur as discontinuous patches, and cannot be followed for more than a short distance. Some of the joints of the sills are parallel to the movement planes in the adjoining slates, and there is a tendency to a parallel structure corresponding with these joints. Many instances may be observed where the minor faults in the slates have also affected the mica traps and heaved them. These rocks, besides being affected by fractures subsequent to their consolidation, have sometimes been injected into brecciated strata, so that what would have been a single sill is represented by two or three discontinuous veins. Moreover, brecciation has continued after the consolidation of the erupted material, the slate along the margin exhibiting a curious zone of very fine brecciation, which has been brought about by stress acting on the indurated margin that has been hardened by the sill. The mica traps do not penetrate the cross courses (N.N.W. faults), and are probably older than those fissures. So far as the evidence in the West of England is concerned, they penetrate, according to my colleague Mr. Ussher, sediments in Devonshire as high as Permian.

MICA TRAP FROM TRELISSICK.

A specimen obtained from the mass on the coast about half a mile S.S.W. of Trelissick (3,365), examined under the microscope, shows a large quantity of biotite in long broad laths, some of which are bent, and variations from striated laths, greenish to brown in colour, to dark brownish decomposed masses devoid of structure. Apatite, in elongated prismatic and in transverse sections, is very abundant and forms a striking characteristic of this rock. Turbid felspar without striation, probably orthoclase, seems to behave as a ground mass, together with calcite and quartz; sphene is also present. This is probably the rock described by Mr. J. A. Philips in his paper on the "Rocks of the Mining Districts of Cornwall,"[1] and referred to by Mr. Teall (in his work on British Petrography, p. 355) as the rock in which augite has been detected.

The above slide (3,365) contains a green decomposition mineral, in which faint cleavage traces are discernible, as a pseudomorph which may possibly represent augite.

Besides the evidence of the distortion of the mica in this slide, Mr. Teall[2] has described a specimen from the Helford River in which "the plates of mica have frequently suffered mechanical deformation."

[1] *Quart. Journ. Geol. Soc.*, vol. xxxi. p. 337.
[2] See *British Petrography*, p. 357.

GREENSTONES.

LITHOLOGICAL CHARACTERS.

In this district the greenstones occur as sill-like masses. They vary from coarse amphibolites or epidiorites to fine-grained rocks of basaltic texture, and from masses which are highly sheared to others which have suffered no mechanical deformation. Microscopic examination leaves no doubt that the coarser masses are altered gabbros, while those of finer texture were for the most part originally basalts. Some of the highly sheared and decomposed varieties are too altered for satisfactory determination. The coarse gabbro-like masses are undoubtedly intrusive, and this area furnishes no evidence that the finer-grained masses were poured out at the surface as lavas; indeed, from the absence of either volcanic agglomerates or tuffs, it is safer to conclude that these rocks are confined to the intrusive phase.

GREENSTONE OF TRELUSWELL AND PONSANOOTH.

A typical greenstone occurs skirting the granite in the aureole of contact metamorphism between Treluswell and Ponsanooth, while a larger sill of the same type occupies a similar relative position between Pengreep and Treviskey, and may be a continuation of the same intrusion after being lost beneath the surface for upwards of a mile. The ground is too obscure for the investigation of their relation to the slate which encloses them.

The mass between Treluswell and Ponsanooth is mainly of very coarse texture. A specimen pre-

pared for the microscope from Bellevue, near Penryn (3,367), shows it to be a massive amphibolite resulting from the alteration of a coarse dolerite or gabbro. Prior to thermo-metamorphism the rock was decomposed, and while the original felspar remains, the old decomposed basic material is replaced by a mat of actinolite. There is a sporadic appearance of actinolite amongst the felspars, probably due to a migration of the decomposition products. Iron ore is present in process of alteration to granular sphene, as well as fine needles of apatite, some of which are broken and may possibly be original.

A specimen from the quarry near Ponsanooth (3,371) is essentially a similar rock, but exhibits a little foliation and contains less felspar. It is a massive amphibolite, consisting of similar hornblende to the last, with the same feathery habit. The felspar is mainly in a granulitic condition, especially in the shear planes. Besides some magnetite there are some flakes of pale brown mica, probably the direct result of contact alteration.

GREENSTONES OF PENGREEP AND TREVISKEY.

The sill between Pengreep and Treviskey is more variable in its texture. While portions of the mass are as coarse as that just described, the greater part of this rock is of fine grain. A quarry at Devis (half-mile S.S.W. of Gwennap) exhibits its variable character within a limited section. Here patches which are crystalline succeed bands of so fine a texture that the crystalline character is not detected; the two types alternate sharply with zones which are very finely sheared. Some

of the finest-grained parts of the very compact rock have a purple hue, and recall the hornfels type of alteration. The mass has evidently undergone considerable mechanical movement, the finer more compact zones and those of coarser crystalline condition having been packed and squeezed together, and shearing set up along the latter type. This rock strongly approaches the type of greenstone we see near St. Ives, which has been so profoundly metamorphosed by the granite of that region, and some of its banded structures somewhat recall the banded hornblendic rocks of the Lizard area. The rock is partially mineralised with secondary pyritous products, while quartz veins apparently mixed with epidote cross the prevailing banding. Some of these fine cross veins seem to be hornblendic.

A specimen from Pengreep, examined under the microscope (3,368), of the coarse gabbro-like type is an amphibolite or epidiorite very similar to the specimen from Bellevue (3,367), except that it contains foliation planes. The original felspars still remain, and the secondary actinolite pervades the felspars more than in the former rock. The iron ores in this rock are well preserved.

Another specimen from the same locality, but of the fine-grained type and closely approaching in character the purplish variety described from Devis, may be described as a fine-grained amphibolite or epidiorite (3,369). The rock shows no sign of crushing, beyond traces of a few shear planes like those in the micro section from Pengreep. The felspar is not altered, and the feathery hornblende is of the

same type as in the preceding specimens. There are traces of the old structure still remaining.

GREENSTONES OF INTERMEDIATE COMPOSITION.

Those types of greenstone with which we have hitherto been dealing represent the more basic phases of intrusion of doleritic type. The next type is more acid and corresponds to intrusions of intermediate composition. I will first of all describe a rock of this type beyond the special area we are considering, which I had the opportunity of examining at Newlyn in the company of my colleague Mr. S. B. Wilkinson, as the rock occurs there in a comparatively fresh condition. Under the microscope (3,372) it is seen to be entirely unsheared. The plagioclase felspars are fairly fresh and undisturbed. The hornblende is somewhat of the same type as in the rocks from Pengreep, but the fringes of the crystals and the dispersed fragments are more in the nature of grains and nests than needles; consequently the feathery appearance is absent. The biotite has precisely the same habit as in the former rocks. The alteration of pyroxene to hornblende and biotite is mainly paramorphic. The rock is a somewhat basic andesite.[1]

[1] Since this paper was communicated my colleague Dr. Pollard has prepared a chemical analysis of a specimen obtained from Gwavas quarry, Newlyn, which clearly shows that this rock belongs to the Andesite group. The analysis is as follows:—

SiO_2	59·84	FeO	7·03	K_2O	2·76	H_2O 105°	0·14
TiO_2	·64	MnO	·12	Na_2O	6·52	„ above	0·31
Al_2O_3	15·71	CaO	3·71	S	·10		
Fe_2O_3	1·68	MgO	1·37	P_2O_5	·20		100·13

BaO, Li_2O not found. Specific gravity, 2·80.

GREENSTONE OF FLUSHING.

A greenstone mass that is evidently closely related to the Newlyn rock passes in a north-easterly direction through the northern part of Falmouth. It is again seen across the Penryn Creek at Flushing, where it widens to about two hundred yards, and then disappears. It is generally much altered, and in parts seems to be sheared. It is finely crystalline, and its main constituents, as seen by the naked eye, appear as decomposing felspar and a green micaceous or chloritic mineral with numerous decomposition products. Under the microscope (3,373) it is seen to be largely made up of felspar similar to that in the preceding specimen from Newlyn (3,372). Although highly decomposed, it has not been granulitised, and in this respect also resembles the preceding slide. The felspars, however, are not so fresh, and chloritic and serpentinous matter is abundant. There are traces also of the green mineral being disposed in the nature of nests and grains similar to the hornblende arrangement in 3,372; in fact, except for its more advanced state of decomposition, it bears a striking resemblance to that rock, the hornblende and biotite being represented in the Flushing specimen by chloritic and serpentinous material. The latter rock, however, occurs just outside the aureole of metamorphism of the granite, while the Newlyn example is in the midst of an extremely hornfels'd area. Had the Flushing rock been subjected to

thermal metamorphism, the two would probably have been identical, as no doubt they were in their original condition. Mr. Collins has apparently grouped this rock with the mica traps, doubtless from its advanced state of decomposition, combined with the absence of hornblende and the resemblance of the green chloritic matter to decomposing mica. He gives a chemical analysis of his rock from Flushing, which contains 55·45 per cent. of silica, 1·48 per cent. of potash, and 4·30 per cent. of soda, with a specific gravity of 2·66. The rock would therefore appear to occupy a position on the borderland between the basic and intermediate types. This and the Newlyn rock might be described as types of somewhat basic andesite, or andesitic dolerite.

RELATIONS OF MICA TRAPS AND GREENSTONES TO THE GRANITE.

The question arises what relations these greenstones and minettes bear to the granites and elvans. At first sight the metamorphism which these greenstones have undergone would appear to mark them off so completely from the granites and elvans that they might naturally be assigned to widely separated intervals of igneous activity. The granite has not only effected contact metamorphism on the greenstones, but the latter have also been pierced by elvan dykes. But on the other hand, if it is conceded that the intrusion of the granites and elvans was coeval with the closing phase of the earth movements which have deformed the slates,

the interval between the greenstone and granite intrusions may be bridged between narrow limits; indeed, if it can be shown that some of the former have altogether escaped mechanical deformation, it is difficult to escape the conclusion that such interval did not exist, and that the intrusions are progressive.

A glance at the map will show that, speaking generally, the greenstones occupy a marginal position in respect to the granite. In the area to which this paper particularly refers, their occurrence is rare outside the metamorphic aureole which surrounds the granite border. They have consequently been subjected to thermo-metamorphism as the result of contact action superimposed upon dynamic metamorphism due to earth stresses. The investigation of their petrological relationship to the granites is therefore complicated by the partial, or in many cases complete, destruction of the original minerals, together with their mode of association.

Our greenstones of the district are seen to be composed of amphibolites, epidiorites, and rocks in which the ferro-magnesian constituents are represented by chloritic and serpentinous material. Further, they are seen to vary in composition from basic to intermediate; not only in composition, but we see every gradation in the amount of mechanical deformation they have undergone. Moreover, this type of alteration in the intermediate rocks is less pronounced than in the basic. This is more especially demonstrated by the state of preser-

vation of the original felspars. From the evidence, therefore, at our disposal, we seem justified in concluding that these andesitic types were intruded when the force of the stresses had somewhat diminished, and possibly separated by no great interval from the irruption of the granites. While evidence has been submitted that these plutonic masses themselves were subjected to stress before their final consolidation, it would appear that when the elvans were intruded a state of equilibrium had been finally established. The mica traps of this area may possibly belong to some part of the interval separating the andesitic greenstones from the elvans. They show no evidence of shearing,[1] but, on the other hand, they form such discontinuous patches amongst the slates that it seems reasonable to assume that they have been subjected to movements from which the elvans have escaped by reason of their intrusion at a later period. It is, of course, conceivable that the elvans have successfully resisted minor stresses to which the minettes have more or less succumbed.

I have observed that in the case of the Carn Menelez granite we find a progressive crystalline texture increasing in coarseness from the periphery to the central core, and decreasing in basicity in a similar direction. Moreover, the mass as a whole is permeated by aplite veins more acid and more finely crystalline than any part of the parent rock.

[1] As noted, however, on a previous page, the mica, which is the dominant mineral of this rock, shows evidence of mechanical deformation.

The evidence of differentiation in this granite, while not of such a marked nature as that found to exist amongst other plutonic masses (one of which, in conjunction with my colleague Mr. Kynaston, I have lately described),[1] is yet sufficiently distinctive to demonstrate its occurrence.

When we turn, however, to the larger question and attempt to investigate the genetic relationship of the igneous assemblage as a whole, we are confronted with the fact that while some of these rocks retain their original structures, in others they are so far obliterated as to render them useless for comparative study. In so far as the granites and elvans are concerned, their affinities are so pronounced that their petrological relationship is obvious. In the case of the greenstones, however, both basic and intermediate, we can no longer trust petrological comparisons, but fall back on geological considerations based on the nature and extent of their deformation and mineral alteration, taken in conjunction with their relations to the granite intrusions and to the earth stresses with which we suppose these latter to be linked.

From this point of view it has been pointed out that the elvans are the latest, while the mica traps,[2]

[1] *Quart. Jour. Geol. Soc.*, vol. lvi. 1900, "Kentallenite and its relations to other Igneous Rocks in Argyllshire."

[2] Although rocks of this group pierce Permian strata in Devonshire, and the minettes of this area may possibly be of the same age, yet in spite of their restricted occurrence the evidence, so far as it goes, points to their having been subjected to stresses from which the elvans have been free; but, as I have already pointed out, it is possible that the different powers of resistance of the two rocks may sufficiently account for the facts.

which seem to have shared in somewhat earlier stresses, would come next. These would be preceded by the granite, which consolidated under such conditions of stress that parallel structures have been impressed on it. The acid type of greenstone, although demonstrably older than the granite, has suffered comparatively little from earth movements, while the amphibolites and epidiorites exhibit variation from types in which the original structure is partially preserved to others in which it is entirely obliterated. From this reasoning, therefore, it would appear that these igneous rocks were successively intruded during the operation of powerful earth stresses which have modified the palæozoic sediments. While some of the greenstones may be older than these movements, it is difficult to believe that others, notably the andesitic type, could have been subjected to them in their fullest intensity. Again, the elvans and the mica traps were intruded when earth movements had ceased. But the interrelationship of the granite and elvans is apparently conclusive, notwithstanding their progressive position in respect to the earth movements. There should be no objection, therefore, to assigning a common geological epoch for rocks that have been intruded during the operation of these movements, which, as we have seen, include some of the greenstones as well as the granite. Similarly there need be no great hesitation in grouping together the greenstones which had suffered little from those which are highly altered, and were presumably intruded at

a time when these earth movements commenced, or before they began to operate.

In the absence of direct petrological evidence it behoves one to proceed with caution, but from the geological considerations which I have set out the members of this igneous assemblage may be inter-related, and have originated from a common magma. This hypothesis is, indeed, supported by the fact that it would include a connected series of igneous rocks from basic to acid, which would also represent the order of intrusion. If, on the other hand, we separate the greenstones from the granites, mica traps, and elvans, we have one group (greenstones) consisting of basic and intermediate rocks, and another group made up of intermediate or acid rocks. The one group is seen to be without acid types, while the other is without basic representatives. While regarded separately, the groups are complementary one to the other; as a single rock assemblage they form a connected series, following the usual order of intrusion. If these are in reality two igneous groups, having no relations to one another, their complementary character must be regarded as a singular coincidence when considered alongside of their geographical distribution.

CHEMICAL AFFINITIES OF GRANITES, MICA TRAPS, AND GREENSTONES.

If we consider the chemical composition of these rocks, there would at first sight be ground for the

belief that a comparative study of their chemical analyses would throw light on their origin. The granites, for instance, besides the ordinary minerals common to such rocks, contain tourmaline and lithia mica as original constituents.[1] They should yield, therefore, to analysis quite appreciable quantities of boracic acid, fluoric acid, and lithia. Now if it could be shown that these compounds exist in any appreciable extent in the greenstones and mica traps, we should have a valuable link common to the entire group. The relations between the granites and elvans being so obvious need not be further discussed.

A large number of the greenstones and mica traps have been analysed by Mr. J. A. Philips and by Mr. Collins; but these minor compounds, unfortunately, do not appear to have been sought for. Mr. Collins, however, adds to his analyses of the mica traps that in addition to phosphoric acid and manganese they all contain lithia and fluorine. But, as I have shown earlier, Mr. Collins' list of mica traps includes rocks that I place amongst the greenstones, and his analyses relate to both types. It seems, therefore, that these special compounds, lithia and fluorine, are common to the greenstones, granites, and mica traps, and so far as this evidence goes it is a connecting link between them. It must be confessed, however, that in the absence of more precise information bearing on the relative

[1] See analysis from Carn Brea, quoted earlier, in which lithia was found by Mr. Philips.

distribution of these compounds which the various types contain, this method of comparison does not carry us very far. It is also necessary to bear in mind the possibility of small quantities of these compounds having been introduced into the greenstones and mica traps subsequent to their intrusion, due to a migration of material, analogous to the secondary depositions which I have considered to take place in the granites as the result of the solution, migration, and subsequent redeposition of mineral matter. In the case of the granite, however, the original and secondary material are both contained within that mass; while in the greenstones and mica traps the secondary material might possibly have been introduced from outside sources.

Before quitting this branch of my subject I would observe that the arguments I have pursued are by no means conclusive for linking the greenstones with the granite; indeed, a superficial examination of the region would leave very little doubt in the mind of the observer that the former were of far greater antiquity than the latter—the explanation naturally suggesting itself that the greenstones express the intrusive phase of the Devonian lavas that were poured out at the surface in the West of England; for although the evidence negatives the presence of such lavas in West Cornwall, I have pointed out in a former paper[1] the probable Silurian age of our sediments, so that the Devonian lavas

[1] *Trans. Royal Geol. Soc. Cornwall*, vol. xii. part 6, 1901, page 29.

existing further east may have been removed by denudation in this area. While doubts may exist as to the interval separating the greenstones from the granite, I have no hesitation in linking the foliated granite with the normal type of that rock. On the other hand, it must be conceded that the pillow lavas (described by Messrs. Fox and Teall from Mullion Island,[1] and which I have also shown to occur at Gorran Haven on the same geological horizon, and as fragments in the conglomerate at Nare Point intermediate between those localities), the Ordovician age of which may be safely accepted, have largely escaped metamorphism. At Mullion Island the protection afforded by the igneous rocks of the Lizard complex has been the dominating factor in their preservation from the results of the movements which I have indicated earlier to have proceeded from the south-east. At Gorran Haven, while they have suffered severely by mechanical deformation, the solid portions of the rock retain their original mineral character, notwithstanding the fact that they must have been subjected to the stresses throughout that region since Ordovician times. From this point of view, therefore, it might be argued that the andesitic greenstones, which I have claimed to be similarly unaffected, might likewise have escaped metamorphism; for whether they are to be considered as of Devonian or of Silurian age, they are at any rate younger than the pillow lavas of Gorran Haven. It must be re-

[1] *Quart. Journ. Geol. Soc.*, vol. xlix.

collected, however, that while the latter are situated far beyond the region occupied by the granite intrusions, the former occur within that region; and from the intensity of the metamorphism to which the basic greenstones have been subjected, we must conclude that either the stresses have been more severe, or that thermal conditions have prevailed to such an extent that metamorphism proceeded further within that zone than beyond it. How far the variations in metamorphism within such zone can be reconciled with the effects produced by contact alteration of the granite on rocks which had already been subject to dynamic metamorphism, is an obscure problem, and in the present state of our knowledge it will be well to keep in view the possibility of progressive intrusions from a common magma.

MINERAL LODES.

I now come to the last division of this paper, in which I shall attempt to trace a connection between the rocks I have described and the relationship of their structures with the phenomena of the mineral lodes. I may remark at the outset that I approach this part of my subject with great diffidence. While the study of the great geological features can to a very large extent be satisfactorily carried on from above ground, our knowledge of the mineral lodes is necessarily derived from their underground exploitation. Even where every facility is at hand in a district where

mining operations are active, investigations have to be carried on under unfavourable conditions, with feeble illumination; and as each section that is laid bare is more or less destroyed as the work proceeds, scientific investigations are necessarily restricted. Above ground our geological sections are, generally speaking, available for re-examination and comparison; below, they are progressively exposed and then obliterated. Even when we are content with the examination of the walls of lodes whose material has been removed, the rock is soon coated with a surface encrustation which more or less conceals its nature. Mining operations in Cornwall being unfortunately restricted, there are few subterranean sections that are available for our inspection. My own investigations underground have so far been strictly limited, and in the nature of preliminary reconnaissances. My remarks, therefore, in this connection must be considered also as of a preliminary nature, and the views to which I give expression may be modified as the work of the survey proceeds. But as these initial speculations are based largely on my geological investigations of the area, they form a necessary sequel to them, if they do not form indeed an integral part of the greater geological problem with which they are involved.

In his classic report,[1] De la Beche remarks that though the study of phenomena in connection with mineral veins may have given birth to geology, the

[1] Work previously cited, p. 50.

"geological theories of the day are less advanced on the formation and filling of mineral veins than on any other part of the general subject." Had this great investigator been alive to-day, he would have seen no reason to modify his views expressed over sixty years ago, except in so far that our knowledge of this branch of geology occupies relatively a more retrograde position than it did at that time. Since the publication of De la Beche's report, the literature pertaining to Britain on that subject is extremely meagre, considering the long interval of time that has elapsed. The genesis of ore deposits has, however, occupied a more prominent position on the Continent and in America, but notwithstanding the accumulation of data, the modern theories on the origin of mineral veins are no more than theories, which cannot be said to exact general acceptance. Certain writers have indeed enforced the doctrine that ore deposit has been restricted to the outer crust by the action of underground waters. There are rival theories, of ascending, descending, and laterally acting waters, to account for these deposits; while others hold that the same lode may be enriched by all these processes. According to this theory, lodes are found to be richer in their upper limit and poorer as they get deeper, due to the upper portions having been enriched by solution and redeposition from that part of the vein which lies near the surface. On this hypothesis, before the upper portion shares in the disintegration and denudation

that are going on at the surface, it has already parted with its metalliferous contents, which have gone to enrich the lode below. Consequently, according to this view, the enrichment of the lodes must be descending at a corresponding rate with surface denudation. Further, the lode must be increasing in value by secondary enrichment at a proportional rate. It is supposed, therefore, that the mineral veins which are in course of exploitation are of late geological age, probably few extending beyond Tertiary time. If we accept this theory in its entirety, we cannot well escape the conclusion that the ores are of comparatively recent geological age.

For a lucid exposition of the actions of underground waters in their connection with ore deposits, the reader is referred to the publications of Van Hise,[1] who, together with other American writers, has based his researches on the supposition that mineral lodes have been formed comparatively near the surface of the earth by means of concentration resulting from the action of circulating waters.

LODES MAINLY FISSURE VEINS.

Whatever may be the *modus operandi* which has resulted in the concentration of the mineral ores, there can be little doubt that the metalliferous lodes of Cornwall occupy in the main planes of fissure

[1] See *Journal of Geology*, Chicago, 1900, vol. 8. See also papers by Messrs. S. F. Emmons, W. H. Weed, C. R. Keyes.

analogous to ordinary faults. The published evidence on this point is so overwhelming as to require no further demonstration. In addition, however, to the substances which are usually found in normal fault and joint veins—such as quartz, calcite, etc.—we find a certain proportion of the mineral ores, the amount of the latter being extremely small as compared with the former. Now there can be little doubt that the ordinary substances which compose the vein material of rocks are derived by solution from the containing rock masses—they bear, in fact, a definite mineral relation to those rock masses; so that in siliceous districts we find quartz the principal vein ingredient, in limestone areas the corresponding vein stone is usually calcite, while in rocks containing epidote we frequently find that material associated with quartz in the veins, and so on. Although calcite is such a common vein substance, yet when we examine the veins in the slates of West Cornwall we find that mineral seldom or never entering into the composition of such veins; while, on the other hand, one of the most striking characteristics of these slates is the absence of calcareous material.[1] The chemical relations of the veins and the enclosing rocks sufficiently demonstrate that the material of the former has been derived from the latter. If we assume, therefore, that the common substances of mineral veins which form by far the greater part of their mass are derived from the

[1] See *Summary of Progress*, 1900.

enclosing rocks, the question arises, On what grounds can we dissociate their metallic contents from a like origin? It is true that the chemical relation between the non-metallic portions and the containing rock is everywhere apparent; while in the metallic constituents such relationship, if it exists, is not so evident. On the other hand, even in this concentrated form they bear such a small proportion to the non-metallic vein stone that they might easily be derived from correspondingly small components of the enclosing rock mass, and so limited in amount as to escape observation.

TECTONIC ARRANGEMENT OF THE MINERAL LODES.

Before discussing this question further, it will be convenient to consider the tectonic arrangement of the lodes in their relationship to the rocks amongst which they occur. It will simplify this discussion if I confine my remarks to the main system of tin and copper lodes of the region, which have been so carefully described by previous observers that their main features are matters of common knowledge.

1. In their distribution these lodes are mainly confined to the granite areas and the slates that are immediately contiguous.

2. They have a general direction of about E.N.E. and W.S.W., corresponding with the direction of the elvan dykes, with the general axis of the granite masses between Dartmoor

and the Isles of Scilly, and with one of the great joint planes of the granite, viz. the *tough-way* joints.

3. They have an average hade of about seventy degrees, with a general tendency to dip towards the granite.

4. They are often crossed by a set of fissures at right angles, locally known as cross courses. These cross courses have an approximate direction N.N.W. and S.S.E., thus corresponding to the *cleaving-way* joints of the granite. They are later than the elvan dykes and the tin and copper lodes.

SOURCE OF THE METALLIC ORES.

The general facts above enumerated will suffice for the question immediately before us, viz. the source of the ores of tin and copper contained in these lodes.

The first point that naturally suggests itself is whether they are derived from the enclosing rocks, or whether we are to seek more subterranean sources for their supply. Looking to their distribution in relation to the granite, this rock appears to me to offer a promising field for our inquiry.

It has long been known that the minerals of igneous rocks contain many of the metals. Sanderberger[1] has shown that if a small quantity of the common rock-forming minerals—mica, olivine,

[1] See Teall, *British Petrography*, p. 37.

augite, and hornblende—be taken, many of the metals found in mineral veins can be detected. Olivine frequently contains copper, nickel, and cobalt, with sometimes tin and arsenic in very small quantities; copper and cobalt were constantly found in the augite of basic rocks; nickel, lead, tin, zinc, antimony, and arsenic being limited to the augite of certain localities. Hornblende was found to contain nickel, copper, arsenic, and cobalt. The micas, however, were the richest in the heavy metals. Thus lithia micas always contained tin, and, except lepidolite, arsenic, copper, and bismuth in addition. Copper was commonly present in the potash micas. Becker has shown the existence of silver and gold in the augite of the igneous rocks in which the Comstock lode is situated. Boron and fluorine occur in tourmaline. Boron also occurs in many micas. As Mr. Teall has remarked, "these observations show that the so-called rare metals are very widely distributed, and that they can only be said to be rare in the sense that they are not present, as a rule, in sufficient quantity to be detected by the ordinary methods of analysis."

The igneous rocks of the world have been divided into an acid group and a basic group, between which we get intermediate forms. These rocks present every variation, and shade imperceptibly into one another so that the different types have no precise definition or border line. Speaking generally, however, the extreme types have special

characteristics, and are thus far defined that each possesses a group of minerals which is more or less confined to that type. In addition to the rock-forming minerals that characterise the acid and the basic groups, Professor Vogt has attempted to show a corresponding assemblage of the metallic ores which accompany those groups. In that grouping he places copper as a characteristic associate of the basic rocks and tin as a characteristic associate of the acid rocks.

This classification would seem to exclude the probability of copper being derived from a granite. But, as previously stated, we get every variation in the mineral composition of rock masses. The mineral aggregations characteristic of the extreme types only holds good generally. Minerals which have a particular affinity for the basic group frequently transgress into the acid group, and *vice versâ*. Similarly, in respect to the metallic ores, we may expect corresponding variations. I may mention, for instance, an extreme case that has fallen under my own observation. Nickel is a specially characteristic element of the ultra basic rocks, yet it occurs as an ore amongst siliceous schists near Inveraray, in association with huge masses of quartz porphyry.

I may remark that Professor Suess has recently added copper to Vogt's acid group—not, however, as a characteristic element, but rather as an accessory whose affinities are not limited to the basic. Tin, on the other hand, is noted as a characteristic

element of the acid group, and which does not transgress the limits of that group.

If we refer again to the researches of Sanderbergher, we note that lithia micas *always contained tin*, and except in the lepidolite variety copper in addition. Copper was detected, in association with other metals, in the black micas of certain granites. The black mica of propylite (an igneous rock of the intermediate group) contained copper. Copper was the only metal commonly found in the potash micas.

It is also well known that tourmaline contains boracic and fluoric acid, and micas also contain the former.

Now when we look at the mineral constituents of the Carn Menelez granite, and notably the micas and tourmaline, we see the possibilities of large quantities of copper and tin (in addition to many other minerals common to these lodes) being disseminated among its minerals, together with a vast amount of boracic and fluoric acid.

It is true that tourmaline is common as a secondary mineral in the granite; but that it occurs also as a primary constituent, and often in considerable quantity, is undoubted. This is confirmed by Mr. Teall,[1] who also remarks that "exhalations of boracic, fluoric, and other acids, accompanying, it may be, the final stages of igneous activity, have evidently exerted a profound mineralising effect not only on the granites, but also on the surrounding rocks."

[1] See *British Petrography*, p. 315.

De la Beche[1] states that an elvan cutting through the Mulvra Mine in the St. Austell district "holds nests of yellow bisulphuret of copper, apparently isolated, and varying from even several tons to a few ounces in weight." He also records the fact that Mr. R. W. Fox obtained small nests of plumbago, similarly dispersed, from an elvan at Restronguet Creek. The geneses of the tin and copper ores seem bound up with one another. They occupy a similar horizon in regard to the granite, commonly occur in the same fissures, and are approximately of identical age, in marked contrast to the ores of lead, zinc, and allied metals, which are of more recent origin, and not restricted to the plutonic centres.

The existence of copper in the granite and elvans does not necessarily imply that it is confined to the acid portion of the magma from which this granite may have differentiated. We have no evidence that the more basic differentiation, if it exists as such, is anywhere visible. On the other hand, if the greenstones represent these products, they are possibly richer in this metal than the granites. It must be recollected that these masses are, in comparison, of insignificant extent, and chemical conditions may have been unfavourable for the secondary concentration of this product within their limited compass, although they may have yielded this ore in sufficient quantity to the solvents that searched them. In this connection it is worth

[1] Work previously cited, p. 182.

noting that the principal lodes are situated near the granite margin. So far as it goes, this evidence may imply the magmatic concentration of the ores on marginal lines, corresponding, as we have seen, to the distribution of the greenstones.

There seem, then, to be reasonable grounds for the opinion that the metallic portions of the lodes of copper and tin may have been derived from the granite. This would bring the source of the metallic ingredients in harmony with what we suppose to be the source of the non-metallic ingredients, viz. the rock masses which are adjacent or in reasonable proximity.

This in no way invalidates the possibility of these concentrations being supplemented by metallic vapours from below, as we suppose the granite itself to have been irrupted from lower depths, and metallic vapours may have continued to ascend subsequent to the granite intrusion. But if the rock mass itself contained these elements there is no necessity for calling in the aid of more subterranean sources to account for their presence in the mineral lodes.

PREVAILING THEORIES REGARDING ORE DEPOSIT.

As I remarked earlier, there are various theories to account for the concentration of the metallic substances in lodes. While some hold that the metallic deposit has been effected by the agencies of electric currents, others refer these processes to sublimation by metallic vapours, or a transfer-

ence by heated waters from subterranean sources; while, lastly, these products are supposed to be brought about by the action of waters from meteoric sources, which sinking to the limits of the zone of fracture of the earth's crust rise again to the surface by the force of gravitation. This last theory implies underground circulation to be unceasingly at work over every portion of the outer crust of which that zone consists. The constant passage of water over every particle of the entire rock mass removes material in solution and re-deposits it by chemical precipitation along lines of fissure, which are the main channels to which such waters ultimately converge. As rocks are not absolutely impervious, in this way the entire mass is being constantly searched and subjected to a process of leaching. This theory, in its present acceptation, regards ore bodies as essentially surface deposits, confined to a thin zone near the earth's surface—in other words, the outer belt of the zone of fracture—and referable to late geological time, few ore deposits being of pre-Tertiary age. I will now briefly discuss these rival theories as regards their application to the mineral lodes of Cornwall.

THE ELECTRIC THEORY IN ITS APPLICATION TO CORNISH LODES.

The late Mr. R. W. Fox applied the electric theory to account for the mineral lodes of Cornwall. Their deposit along east and west fissures was

inferred by him to be governed by the action of electric currents which traversed the earth at right angles to meridian lines. De la Beche, following a like argument in connection with the great divisional planes in the West of England, after noting the general agreement of one set[1] with the direction of the magnetic meridian, both in igneous and sedimentary deposits, was led to think that polar forces "governed the arrangement of the component matter of the rocks they traverse during consolidation, either from the cooling of the former (igneous) or the chemical changes which have taken place in the latter (sediments)." By this theory he has to assume a general progression of fissure formation in this general direction, and he admits that one set of beds must have been influenced during consolidation, before the advent of the next, which followed similar lines.

De la Beche's hypothesis, however, would require a more universal parallelism of these phenomena over the surface of the globe before it could claim to support the influence of magnetic force. As a matter of fact, periods of intense stresses have been frequently repeated in geological history, and the resulting planes of disruption, while showing a parallelism over large regions as regards that particular epoch of stress which evolved them, do not display such parallelism as regards the groups of other geological age.

[1] This is the set of N.N.W. or cleaving-way joints to which I have already drawn attention.

As I pointed out earlier, our main lodes and elvan dykes occur along fissures having a general parallelism. These are crossed in approximately a perpendicular direction by a set of fissures (cross courses) which, as De la Beche remarks, coincides, roughly speaking, with the present magnetic meridian.

Now it appears to me that these two groups of fissures can be referred to two distinct geological periods, of which they express the general line of disruption common to each epoch respectively, and that the direction of the mineral lodes on the one hand, and of the cross courses on the other, can be explained by these physical considerations without calling in the aid of electric or magnetic forces.

I have already referred to the fact that the general direction of the lodes and of the elvan dykes corresponds to the general axis of the granite bosses in the West of England. Further, this line of disruption corresponds to the direction of the volcanic band (N.E. to S.W.) which traversed the British Islands in the Newer Palæozoic periods,[1] to which age our igneous rocks are referred. We have strong presumptive evidence, therefore, for connecting these fractures with these igneous intrusions.

After a prolonged cessation of volcanic activity, extending over the Mesozoic ages, renewed igneous action on a colossal scale ushered in the Tertiary period, producing a new set of fissures running

[1] Judd, *Volcanoes*, p. 276.

from north to south.[1] This volcanic band, which has left such imposing relics on the British Isles, along the line of the Inner Hebrides (Skye, Mull, Rum, etc.), and the north-east of Ireland, still contains along its Atlantic prolongation remnants of volcanic activity which have not yet been extinguished. In our Cornish area no igneous rocks connected with this epoch are known to occur, unless we except the phonolite of the Wolf Rock, which may probably be referred to that volcanic zone. Now if there is one fact more striking than another in regard to the fractures of that epoch, it is the existence of an enormous plexus of basalt dykes, which in Scotland occupy fissures running in a N.N.W. direction in regions far removed from the centres of those great volcanic eruptions. In those regions on the geological survey of which I have been for many years engaged, there are numbers of such fissures into which basaltic material has not been intruded, at any rate in their upper limits which are accessible to observation. Coming fresh from that district into Cornwall, I have been impressed with their relationship to our cross courses (N.N.W. fissures). In direction and steepness of hade they have a marked correspondence.

When these facts are considered, and their relation to the earlier fissures, represented by the elvan dykes and the lodes, it appears to me that we have grounds for the opinion that these N.N.W.

[1] Judd, *Volcanoes*, p. 276.

fissures in both areas belong to the same set of events, and that we may look upon our cross courses as of early Tertiary age,[1] as by a similar process of reasoning we may regard our lode fissures as of late Palæozoic age. This argument, so far as it concerns the cross courses, is indeed strengthened by De la Beche's observations, who, in the eastern portion of the West of England district, produces evidence, near Chard, that they are of post-Cretaceous age.[2]

From tectonic considerations, therefore, the fact of the tin and copper lodes being found in a set of fissures having a general direction of E.N.E. and W.S.W. (in spite of the intersection of slightly oblique lodes—viz. counter lodes) and their absence in the cross courses is capable of explanation on the assumption that the two sets of fissures are separated by long geological periods, extending over the Mesozoic epoch. The phenomena of the elvan dykes strongly confirm this hypothesis. Whatever opinions may be formed as to the affinity of mineral ores for a certain direction of fissures under the influence of electric currents, no such controlling element can be called into play in respect to the intrusion of the elvan dykes, and it may be regarded as certain that the uprising igneous material would have filled some of the cross courses if they were in existence. Yet they not only follow

[1] No doubt the orientation of the granite corresponding to the cleaving-way joints (N.N.W.) rendered it easier for these fissures to open along the directions required by these Tertiary stresses.

[2] Geological Report previously referred to, p. 311.

directions corresponding to the lodes, but as a group they show a parallelism equally well marked. The inference therefore is obvious that they occupied fissures of this direction for the simple reason that others were not in existence, and I do not see how we can avoid the conclusion that the copper and tin lodes occur along the same parallel directions for precisely the same reason.

Looked at from this standpoint, therefore, while I do not deny that electrical influences may have had some connection with ore deposits, the geological features of the country lend this hypothesis no particular support.

SOLFATARIC THEORY OF LODE DEPOSIT.

When we consider the theory which is based on sublimations from deep-seated sources of volcanic activity, or the upward transference of material from those sources by thermal waters and vapours—that depending, in other words, on solfataric action—it must be confessed that this possible origin of the metallic ores is not so easily disposed of. From the foregoing pages it will be seen that I regard the filling of the tin and copper lodes as having practically ceased before the formation of the cross courses which I have claimed to be of Tertiary age. Further, although the concentration of these ores may have occupied an enormous period of time, there are no geological reasons for postponing their introduction to such a period, for instance, as that immediately anterior to the Tertiary fissures.

On the other hand, the absence of these tin and copper ores, or their inclusion in inappreciable amount in these later fissures, would appear to mark an interval of considerable importance, during which the conditions affecting their deposition had either ceased or had been considerably diminished in potency. It seems difficult to dissociate this change of condition from that which must have taken place by the final extinction of volcanic activity, represented by the granite and elvan intrusions. This reasoning would probably carry us back to pre-Triassic times for the period in which these mineral lodes were in process of formation. I am aware that in adopting this view of their antiquity I am not altogether in harmony with the more advanced doctrines of the present day in regard to the genesis of ore deposits, but if I am correct in my interpretation of the geological structure of the district, there does not appear to be any escape from this conclusion. Speaking broadly, I regard these mineral veins as following closely on that phase of volcanic activity which is represented by the solidification and cooling of the granite, and the disruptions that accompanied that phase.

UNDERGROUND WATERS AS AGENCIES OF ORE DEPOSIT.

Moreover, this does not invalidate the theory of ore deposit by the continuous circulation of underground water, under ordinary thermal conditions

that relate to the outer belt of the zone of fracture. On the other hand, the application of this theory appears to me to offer a sufficient explanation of such deposit. It affords, at any rate, a simple solution to the continuation of ore deposition, but to a diminishing extent, in Tertiary times. The late Mr. Henwood has stated, for instance, that some of the richest lead veins are found in cross courses.[1] In the same way, although our tin and copper lodes may belong to early geological time, the process of secondary enrichment by leaching of the upper portions of the veins has probably been continued to late geological time. And in this connection it must be recollected that the original lode may have been so uniformly impregnated with the metallic ores that without these secondary enrichments, which have been in the nature of fresh concentrations on an original ore deposit often repeated more than once, it might possess no economic value.

De la Beche has pointed out that the fissures have reopened after metallic substances have been deposited in them.[2] We shall probably be correct,

[1] *Journ. R. Inst. Corn.*, No. xiii. p. 15.—Mr. W. Thomas, manager of King Edward Mine, Camborne, informs me that the cross courses contain many metals, but usually only in small quantities. The Great Byan cross course carries some gold. The great cross course of the Camborne district contains nickel and cobalt. A cross course at Pelyn Wood in the Lostwithiel district carried also nickel and cobalt. While the so-called lode of the uranium mines is north and south, and possibly of the same age as the cross courses, it yields uranium, nickel, cobalt, and other metals.

[2] In a recent paper (*Q. J. G. S.*, vol. lvii., August, 1901) I referred to the recorded occurrences of boulders and pebbles in the

therefore, in concluding that these mineral ores were in process of deposition before the movements connected with the elvan intrusions had ceased. Meteoric waters, on penetrating to these depths, would be raised to a high temperature, thus ores contained in the granitic minerals would be more readily soluble, while the large quantity of boracic and fluoric acid available would still further enrich these solutions; indeed, the association of boron and fluorine in the granite cannot be kept too prominently in view in connection with the precipitation of the ores of tin. Moreover, it is necessary to assume, on the hypothesis that the tin and copper have been dissolved from the granite, that deposition primarily took place along *ascending* currents, for these veins penetrate the slate which reposes upon the granite. Although *lateral-acting* and *descending* waters may all have played their parts, the latter in the concentrations due to secondary enrichment, yet on this hypothesis the dominant factor in the lode deposition is that of ascent. Viewed in connection with the solfataric theory, therefore, the genesis of the lode might be explained on either hypothesis. Personally, however, I incline to the opinion that the original copper and tin depositions were the result of circulating waters penetrating so near the region of

Cornish lode breccias as crush conglomerates. After inspection, however, of the specimens in the Geological Survey collection at Jermyn Street, I must confess that they bear a strong resemblance to water-worn fragments, and may represent a phase when the fissure was opened and traversed by currents of underground water.

diminishing volcanic activity that solutions were effected at high temperatures, and deposited under these conditions by the *ascending* currents. After the effects of these volcanic conditions had ceased to operate, ore deposition continued to proceed along the same lines, but under more normal temperatures, by which tin and copper in appreciable quantities had ceased to be precipitated, except by the processes of secondary enrichment of lodes already existing.

STRUCTURES OF ADJACENT ROCK MASSES AS FACTORS IN LODE DEPOSITION.

It was my intention to have touched upon the enrichment of lodes in parts of their course, and their poverty in others, in their relations to the enclosing rocks. On this point much information is at hand showing not only that there is a disposition for lodes to increase in value in the neighbourhood of junctions with the slate on the one hand, and the granite and elvans on the other; but that in certain localities under apparently similar conditions the reverse is the case. These phenomena seem to me capable of explanation by the fact that lode deposit is not determined so much by the nature of the adjacent rock masses as by the structures displayed by those rock masses, especially in the controlling power such structures exert over the circulation of underground water. Time, however, does not admit of my pursuing this part of my subject further, and its consideration will be deferred to a future occasion.

GENERAL SUMMARY.

My last paper dealt with the structures displayed by the Palæozoic sediments of West Cornwall, in which I demonstrated that those sediments had been subjected to powerful earth stresses, as a result of which they had suffered so much mechanical deformation, that their original characters had been masked, and that we can no longer depend upon the dip of the strata as a reliable index of stratigraphical relationship. On this occasion I have carried those investigations to the igneous rocks, and have endeavoured to show how far these combined structures throw light on the phenomena of the mineral lodes.

Having described the mineral characters of the granite and the systems of jointing appertaining to it, I have shown that these joint planes bear a definite relation to the crystalline arrangement. There are three well-defined joint planes in the granite; one set of vertical joints, having a prevalent direction of N.N.W., is crossed by another vertical set at right angles. These two systems, in connection with a third set more or less horizontal, divide the whole rock into a set of rough prismatic segments. The rock cleaves most readily along planes parallel to the horizontal joints. The next easiest cleaving plane is that parallel to the N.N.W. joints, while the rock cleaves most irregularly parallel to the E.N.E. joints. Not only is there a close connection between the major joints and the

grain of the rock, but the grain itself is dependent on the internal mineral arrangement, and all three phenomena are closely related.

The uniformity in these structural features is not only diffused over the whole granite mass, but is common to the whole of the granites of the West of England. While the granite presents only exceptionally a marked foliated appearance, it has evidently undergone throughout a rude and initial stage of foliation, whereby its component minerals have been forced to rearrange themselves in a definite direction so as to acquire a cleavage. Judging from the data furnished by the district between Gerrans Bay and Truro, there are reasons for believing that the sediments owe their deformation to stresses acting along a N.N.W. direction, which agrees with one of the main cleaving directions of the granite. There are strong grounds, therefore, for assuming that the granite irruptions and the earth movements are not only closely related, but that the latter had not ceased to operate before the final solidification of the former. This reasoning is still further supported by the evidence of two foliated granite sills that flank the granite margin near Penryn, and by the marginal granite at Kennal Vale, near Ponsanooth, acquiring a distinctly foliated or gneissose character, the foliation in both instances coinciding with the cleavage of the adjacent slates.

The constancy of the cleavage planes in the granite may have an important bearing on the

investigation of other regions, as by these means it may be possible to determine the geological age of granites where other methods are unavailing.

Besides the granites and the elvan dykes which have a close petrological relationship, the other igneous masses are greenstone and mica traps. Both sets of rocks have been described, together with their microscopic characters.

The greenstones consist of amphibolites, epidiorites, and rocks in which the ferro-magnesian constituents are represented by chloritic and serpentinous material. Moreover, they vary in composition from basic to intermediate. Not only in composition, but there are gradations in the amount of mechanical deformation they have undergone, the intermediate having suffered less than the basic rocks, and this is more especially shown by the state of preservation of the original felspars. It is inferred, therefore, that the intermediate or andesitic types were intruded when the force of the stresses had somewhat diminished, and possibly separated by no great interval from the irruption of the granites. While evidence has been submitted that the granites themselves were subjected to stress before their final consolidation, the elvans appear to have been intruded after the cessation of the earth movements.

The mica traps of this area possibly belong to some part of the interval separating the andesitic greenstones from the elvans. They show no evidence of shearing, but some of the micas have

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suffered mechanical deformation. In the field, moreover, they appear to have been subjected to movements from which the elvans have escaped.

In the Carn Menelez granite I have found a progressive crystalline texture increasing in coarseness from the periphery to the central core, and decreasing in basicity in a similar direction. Moreover, the mass as a whole is permeated by aplite veins more acid and more finely crystalline than any part of the parent rock. The evidence of differentiation in this granite is sufficiently distinctive to demonstrate its occurrence. But when we turn to the larger question of the genetic relationship of the whole igneous assemblage, we encounter the difficulty that the original structures of some are so far obliterated as to render them useless for comparative study. As regards the granites and elvans, their affinities are so pronounced that their petrological relationship is obvious. In the case of the greenstones, however, we can no longer trust to petrological comparisons, but fall back on geological considerations based on their metamorphism, and their relations to the earth stresses with which the granite irruptions are linked.

From this point of view it has been remarked that the elvans and mica traps are the latest. These were preceded by the granite, which consolidated under conditions of stress, and parallel structures were induced on it. The acid type of greenstone has suffered comparatively little from earth movements, while the basic types have in

many cases been so metamorphosed that all traces of their original structure have been obliterated. It is possible therefore that the whole of the igneous rocks were successively intruded during the operation of powerful earth stresses which have modified the Palæozoic sediments, and that they are inter-related.

This hypothesis is supported by the fact that it would include a connected series of igneous rocks from basic to acid, which would also represent the order of intrusion. If, on the other hand, we separate the greenstones from the granites, mica traps, and elvans, we have one group without acid types, while the other is without basic types. And their complementary character to one another must be regarded as a singular coincidence when considered alongside of their geographical distribution.

Whatever may be the *modus operandi* which has resulted in the concentration of the mineral ores, there can be little doubt that the mineral lodes of Cornwall occupy, in the main, planes of fissure analogous to ordinary faults. The ordinary vein stone of rocks is almost certainly derived by solution from the adjacent rock masses to which they bear a definite chemical relation. If we assume, therefore, that the common substances of mineral veins, consisting of the greater part of their mass, are derived from the enclosing rocks, the question arises how far we are justified in dissociating their metallic contents from a like origin. The propor-

tion of the ore to the common vein stone being so small, even in the mineral veins, they might be derived from correspondingly small components of the enclosing rock mass which would escape observation.

The discussion has been confined to the major system of tin and copper lodes of the region, the main features of which are well known. For instance—

1. These lodes are mainly confined to the granite areas and the slates that are immediately contiguous.

2. Their general direction (E.N.E. and W.S.W.) corresponds with the elvan dykes, the general axis of the West of England granite masses, and with one of the major joint planes of those granites.

3. They are crossed by a set of cross courses (faults running N.N.W. and S.S.E.) which are later than the elvans and the tin and copper lodes.

Looking to the distribution of these lodes in their relation to the granite, this rock offers a promising field for our inquiry.

It has long been known that the minerals of igneous rocks contain many of the metals. Sanderbergher's researches showed that lithia micas always contained tin. Copper was detected in association with other metals in the black micas of certain granites. Copper was the only metal commonly found in the potash micas. Tourmaline contains boracic and fluoric acid, and micas also contain the former.

When we consider the mineral constituents of the granite, and notably the micas and tourmaline, we see the possibilities of large quantities of copper and tin being disseminated amongst its minerals, together with a vast amount of boracic and fluoric acid. If these rock masses, therefore, contain these metallic elements in sufficient quantity, there is no necessity for calling in the aid of more subterranean sources of supply.

There are various theories to account for the concentration of the metallic substances in lodes. While some hold that the metallic deposit has been effected by electric currents, others refer these processes to sublimation by metallic vapours from subterranean sources. While, lastly, they are supposed to be brought about by the circulation of underground waters amongst the outer limits of the earth's crust, which are constantly dissolving the disseminated metallic material and transporting it to situations which are favourable for its concentration. This not only confines the source of the ores to the upper stratum of the crust, but likewise limits their formation to late geological time.

The late Mr. R. W. Fox applied the electric theory to account for the mineral lodes of Cornwall. Their deposit along east and west fissures was supposed to be governed by the action of electric currents, which traversed the earth at right angles to meridian lines. De la Beche argued on the same lines, to account for the direction of the great

divisional planes of the West of England, and supported his opinion by references to corresponding phenomena in other regions.

De la Beche's hypothesis, however, would require a more universal parallelism of these phenomena before they could claim to support the influence of magnetic forces. Periods of intense stresses have been repeated in geological history, while their accompanying planes of disruption show no corresponding parallelism.

I have submitted evidence that the fissures occupied by our tin and copper lodes, and by the elvan dykes, were produced in the later Palæozoic period. It is certain that when the elvans were in course of injection the only set of fissures in existence were these parallel disruption planes, otherwise the uprising igneous material would have occupied them. These parallel lodes, therefore, may be sufficiently explained by physical considerations, without calling in the aid of electric or magnetic forces.

Evidence has also been submitted that the cross courses were formed long subsequently to the lode and elvan fissures, the former coinciding in direction with the planes of disruption that accompanied the volcanic outbursts of the early Tertiary period, while the latter occupy similar relations to the volcanic activity of the later Palæozoic periods.

Looked at from this standpoint, therefore, while I do not deny that electrical influences may have had some connection with ore deposits, the

geological features of the country lend this hypothesis no particular support.

The possible origin of the metallic ores from the solfataric action is not so easily disposed of. There is strong, if not conclusive, evidence that the tin and copper lodes were originated long before the formation of the cross courses the Tertiary age of which I have suggested. Their absence or inclusion in inappreciable quantities in these latter fissures appears to mark an interval during which the conditions affecting their deposition had either ceased or had been considerably diminished in potency. It seems difficult to dissociate this change of condition from that which must have taken place by the final extinction of volcanic activity represented by the granite and elvan intrusions. If I am correct in the interpretation of the geological structures of the district, there appears to be no escape from the conclusion that these copper and tin lodes originated in pre-Triassic times, and that they followed closely on that phase of volcanic activity which is represented by the cooling of the granite and the disruptions that accompanied that phase.

De la Beche has pointed out that fissures have reopened after the deposit of metallic substances in them, so that these mineral ores were probably in process of deposition before the disruption movements following the igneous intrusions had ceased.

Meteoric waters, on penetrating to these depths, would be raised to a high temperature. Thus the

ores contained in the granitic minerals would be more readily soluble, while the large quantity of boracic and fluoric acid available would still further enrich these solutions. Moreover, the deposition of the mineral ores from these solutions must have been primarily brought about by *ascending* waters, otherwise they could not fill the fissures on the superincumbent slate masses which repose upon the granite. Viewed in connection with the solfataric theory, therefore, the genesis of the lodes might be explained on either hypothesis. Personally, however, I incline to the opinion that the original copper and tin depositions were the result of circulating waters penetrating so near the region of diminishing volcanic activity that solutions were effected at high temperatures, and deposited under these conditions by the *ascending* currents. After the effects of these volcanic conditions had ceased to operate, ore deposition continued to proceed along the same lines, but under more normal temperatures, by which tin and copper, in their former quantities, had ceased to be precipitated, except by the processes of secondary enrichment of lodes already existing — the enrichment of the lode having been brought about by the decomposition of its upper limits near the earth's surface, and the redeposition of its metallic contents at a lower level along the lode, these secondary processes being largely brought about by *descending* currents.

Besides a well-known disposition for lodes to increase in value in the neighbourhood of junctions

with slate on the one hand, and granites and elvan on the other, in certain localities, under apparently similar conditions, the reverse is the case. These phenomena seem capable of explanation by the fact that lode deposit is not determined so much by the nature of the adjacent rock masses as by the structures displayed by those rock masses, especially in the controlling power such structures exert on the circulation of underground water.

Royal Geological Society of Cornwall.

THE EIGHTY-NINTH

ANNUAL REPORT

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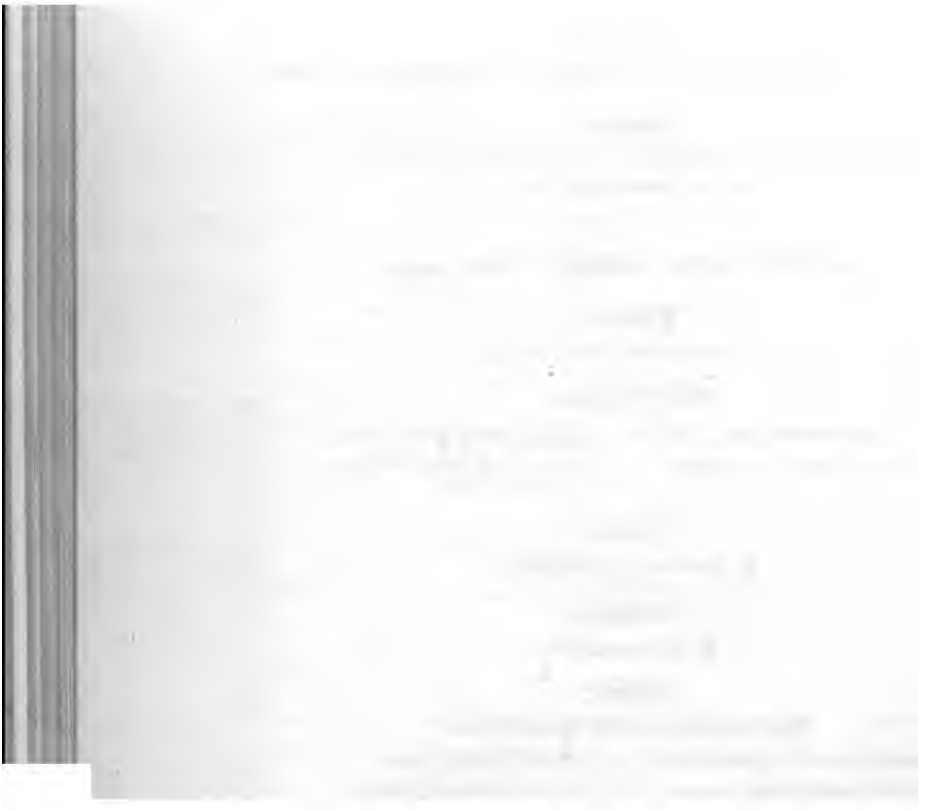

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John Rowe, St. Just.
Stephen Thomas.

The Secretary requests the favour of his being informed of any inaccuracies in the foregoing lists.

THE

ANNIVERSARY ADDRESS OF THE PRESIDENT,

C. LE NEVE FOSTER, ESQ., F.R.S.,

To the General Meeting, November 4th, 1902.

LADIES AND GENTLEMEN,—While endeavouring to choose a subject for my address this year I was met with a difficulty similar to that which I encountered twelve months ago, namely, *embarras du choix*. In making a journey to India during the winter and a trip this summer to the Caucasus, I naturally came across many things of geological interest, not the least being the oil wells at Baku on the Caspian; but it appears to me that the "globe trotter" is not the person to give an address upon the mineral resources of the countries he visits. This task should be undertaken by persons who have dwelt for years in the lands to be described, and who have had fuller opportunities of study than the temporary sojourner. I therefore turn to something quite different, and I propose to spend a short time in pointing out the connection which exists between place-names and mineral deposits.

In so doing I may be accused of stepping beyond the boundaries of our special science, Geology, and of usurping the functions of the geographer. To my mind this objection is not valid, because there is a borderland between Geology and Geography upon which the student of either science may fairly tread. Indeed, there are tracts of common territory other than the one I have chosen, such as the dependence of the natural features of a country, its scenery in fact, upon the underlying rocks, a subject which has been already treated by more than one competent observer.

The connection between the name of a place and a mineral

deposit may arise in various ways. The name of the place may contain—

(1) The name of the actual mineral itself.
(2) The words "mine," "diggings," "pits," "excavations," or "ore," or their equivalents in other languages.
(3) Reference to some natural characteristic of the mineral deposit, such as its colour or the shape of its outcrop.
(4) Reference to the existence of dressing or smelting operations in days gone by.
(5) Reference to the immigration of foreign miners.

I now propose to deal with each of these divisions separately, and to bring forward examples to illustrate my meaning.

(1) NAMES OF PLACES DERIVED FROM THE NAME OF THE MINERAL.

Alum.—The little town of Allumiere, north-east of Civita Vecchia, derives its name from the alum-stone which has for many, many years been quarried and mined in the neighbourhood.

Coal.—The names Coalbrookdale, Coalford, Coalville, are examples which at once occur to the Englishman.

Copper.—Cobre, and Sierra del Cobre, in Cuba, Santa Clara del Cobre, in Mexico, likewise tell us of the existence of ores of copper, but instances need not be confined to the Spanish tongue. The Tartars call a place in the Caucasus Miss Dag, or Copper Mountain, and the same kind of name-giving goes in North America, where we find Copper Basin (Arizona), Copper Cliff Mine (Ontario), Copper Creek (Colorado), Copper Falls (Michigan), Copper Mountain (Arizona), and Copperopolis (California).

Gems.—Ratnapura, a town in Ceylon, is known by name to most people. The word means the "City of Gems," owing to the fact that rubies, sapphires, etc., are found in the neighbourhood.

Gold.—With a valuable, much sought for, and widely distributed metal, like gold, it is not surprising that scores of examples can be cited in which the name of the place, in some way, contains the word "gold" as a noun or an adjective. In our own tongue,

to begin with, we have the Gold Coast. In the Spanish peninsula we find evidence that the Romans worked the precious metal by such names as Valle de Oro, Tasouro, and Rio de Oro. The town of "Ouro preto," in Brazil, was originally "Villa rica do ouro preto," the rich city of black gold. This is matched in Hungary by the word "Arányos," meaning golden, which is affixed sometimes to the name of a river on account of its golden sands.

Iron.—Here again examples are common. In Austria we have the well-known town of Eisenerz, famous for centuries as an iron-producing locality; and judging by the extent of the huge workings rising terrace after terrace for 1,500 feet, the deposit is far from being exhausted. In Northern Africa are names containing the word "Hadid," which in Arabic means iron. Mokta-el-Hadid, near the port of Bona, is a locality which not long ago was furnishing over 1,000 tons of ore a day; it was so called long before the French occupied the country. There are also iron workings at Ras-el-Hadid (the Iron Cape); whilst Gebel-el-Hadid (Iron Mountain), in Morocco, a place where the Carthaginians worked in ancient days, finds its precise equivalent in the Tartar name Damur Dag (Iron Mountain), in the Caucasus. In Germany there is Stahlberg (Steel Mountain), and in Elba, Porto Ferraio (Iron Port). Sometimes the connection is not at first sight apparent, owing to the word having been corrupted in the course of years. In Normandy there are the remains of some old iron workings known to the country people as "Fosses d'enfer," in other words, "Hell Pits." This name is doubtless a corruption of the words "Fosses de fer," or "Iron Pits."

Petroleum and Asphalt.—Rock oil was not worked anywhere on a really large scale until the latter half of the last century, but the existence of an oily material oozing out of the rocks, drying up into a pitchy substance, or forming a layer upon running or stagnant water, so impressed the inhabitants that they indicated the fact in some fashion in the name they applied to the locality. Oelheim, in Germany, is a case in point. The Roumanians have the word "pacura" for "petroleum," and we find many places named, such as "Pacureti," in which it is incorporated. Gebel Zeit, on the shores of the Red Sea, means

"Oil Mountain," and the Burmese town Yenang-yaung means "Oil Creek," and is in the immediate vicinity of the oil wells. Petroleum is known in the Galician Karpathians as "ropa," a word which occurs in the names of many villages, such as Ropa, Ropica, Ropianka, Ropiagóra. This shows that the knowledge of the existence of petroleum is connected with the immigration of the Ruthenes into Galicia.[1]

The names of the places Pitchford in Shropshire, Pece in Sicily, Pechelbronn in Germany, and Pitch Lake in Trinidad, all record the existence of asphalt.

Lead.—Leadhills (Scotland), Bleiberg (Germany), and Gebel-el-Kohol (Tunis) all have the same signification, and all have been applied on account of the existence of workings for lead ore. Leadville, in Colorado, is a modern example.

Salt.—With most people salt is an article of prime necessity. It is not surprising, therefore, that salt deposits should have been sought out in ancient days, and should still be regarded in many countries as mineral deposits of great value. A person quite ignorant of the salt deposits of Germany and Austria might ascertain where many of them lie by consulting a good map and noting where place-names contain the syllable "Salz," "Saal," or their Celtic equivalent "hall." The following may be taken as instances in point:—

Bad Hall.
Hallebach-Thörl.
Haller Anger.
Haller Mauern.
Hall, in Tyrol.
Hall, near Admont, in Styria.
Hallstatt.
Hallthurm Pass.
Reichenhall.
Saalach, a stream dividing Bavaria and Austria.
Saale.
Saalfelden.
Salzach, a river at Salzburg.
Salzberg, near Aussee.
Salzberg, near Berchtesgaden.
Salzberg, near Hall.
Salzberg, near Hallstatt.
Salzberg, near Ischl.
Salzburg, on the Salzach.
Salzburg, Transylvania.
Salzkammergut.

[1] Strippelmann, *Die Petroleumindustrie Oesterreichs*, p. 7.

It is interesting to remark that the names containing the syllable "hall" refer to localities where the extraction of salt was carried on by people of Celtic origin. Just as the Cornishman of the present day is a typical miner, so was the ancient Celt before the Christian era, and he delved for salt, among other things, in Central Europe. The names with the prefix "Salz" appear to have been applied later by German conquerors. In Turkish "tuz" means "salt"; Tuzla (Salt-works) is the old Turkish name for Larnaca, in Cyprus, because salt was made there, and indeed is still made there, by the solar evaporation of sea-water. The Tartar, whose tongue resembles Turkish, speaks of "Duz Dag," or the "Salt Mountain," in the Caucasus. In Bosnia there is a place called Dolnja Tuzla, where salt is extracted at the present time. It was known to the Romans as "Ad salinas," and in the Middle Ages it was called "Soli," from "sol," the Slavonic for salt. The conquerors and occupiers of the country have changed more than once, and yet invariably they have introduced the name of the mineral into the name of the place.

Sand.—Our names of Sandhurst, Sandgate, and Sandling are examples in the case of a common mineral, and if you look out of the window as you rattle past Sandy, on the Great Northern Railway, you are not surprised at the choice of the name made centuries ago.

Silver.—In Southern France, in the department of Ardèche, there is the town of Largentière, so called because silver was worked there some centuries ago.

Sulphur.—Recent eruptions have called our attention to the volcano in the island of St. Vincent known as La Soufrière. Many other volcanoes have received a similar name from the fact that native sulphur is being deposited on the sides of their craters by the decomposition of sulphuretted hydrogen issuing from the earth. The well-known Solfatara, near Naples, is an instance in point. In Japan there is an island called Iwo-to, meaning "Sulphur Island," on account of the occurrence of the mineral.

Tin.—Most Cornishmen will recollect the fact that the

Phœnicians obtained tin from a locality which they called the Cassiterides, or Tin Islands, and the name "Tincroft" is familiar to you.

(2) NAMES CONTAINING THE EQUIVALENT OF THE WORDS "MINE," "DIGGINGS," "PITS," "EXCAVATION," OR "ORE."

I put the two words "mine" and "ore" together because in our tongue they are in some cases used synonymously. The word "mine" may sometimes mean the hole, or excavation, made in the earth's crust, and at others the mineral obtained from it. Colliers will sometimes speak of the "two-foot mine," meaning thereby the seam of coal two feet thick. At a place where large mining operations are proceeding it is not unnatural to hear the works spoken of as "the mine," that is to say the mine *par excellence*, just as an inhabitant of Crewe might speak of the workshops of the London and North Western Railway as "the works," ignoring entirely all small undertakings in or near the town. Two cases specially occur to me. In Spain we have Almaden ("The Mine"), a name given by the Moors to the great quicksilver workings during their occupation of the country and still retained. Near Wrexham are the mine and village known as Minera; this appellation comes down to us from Roman times, when lead ore was worked there in the Carboniferous Limestone, and indeed still continues to be worked. Pant-y-pydew ("the Pit Hollow"), in North Wales, recalls Schachtanaya ("Shaft-place"), in Southern Russia, with its numerous coal pits.

A well-known lead mine in Shropshire is called "Roman Gravels." I fancy that the name "Gravels" is connected with the fact that there are remains of old Roman diggings, and that "Gravels" is equivalent to "Graben," the German word corresponding to "ditches" or "graves" in English. In our tongue the word "grave" is now restricted to a pit for burial, but originally it was applied to any pit. On the borders of Norfolk and Suffolk we find the name "Grime's Graves" given to pits where flints were dug in the Stone Age. "Grime" is probably a corruption of the word "Grim," meaning a "demon,"[1] and conse-

[1] Pointed out to me by Mr. F. Gissing.

quently "Grime's Graves" has precisely the same signification as "Devil's Dyke." The human origin of the old flint pits was forgotten, in spite of the fact that mining for flints at Brandon has not ceased, and the unknown was ascribed as usual to Satanic agency.

Transylvania has various places with names ending in "bánya," meaning "mine-workings." Nagybánya, the "Big Mine," or "Big Workings," corresponds precisely to "Great Work" and Wheal Vor in this country. Offenbánya, Körösbánya, and Abrudbánya are other instances of the same termination. "Kisbánya,"[1] or "Little Mine," is the old Hungarian name for a gold-mining locality. Roumanian immigrants more than a century ago changed the name to Baita, with precisely the same signification in their tongue, and it has since been corrupted into Boicza.

The range of hills dividing Saxony from Bohemia is known as the Erzgebirge, or Ore Mountains, a well-chosen name, as will be readily admitted by anyone who has visited the numerous mining localities they contain. Erzberg, or Ore Mountain, is the name of the high hill which yields so much iron ore near the town of Eisenerz already mentioned.

Pant-y-mwyn and Rhydymwyn, near Mold, meaning the "Ore Hollow" and "Ore Slope," were no doubt given from discoveries of lead ore.

In the peninsula of Sinai there is a valley known as Wady Maghâra, the "Valley of Caves," for it is here that are found the old workings for turquoise, some of which, judging by the hieroglyphics cut on the rocks, must have been carried on many centuries B.C.

Dr. Carl Peters is of opinion that the word "fura" means "mines" or "diggings," and that words containing the syllable "fura" are connected with the existence of ancient gold mines in East Africa. Thus, the name "Injakafura" is considered by him to denote the "place of the great diggings," and he even goes

[1] *Monographie de la Mine d'or et d'argent dite "Rudolfi" appartenant à la Première Société minière anonyme de Transylvania à Boiczà.* Paris, 1900.

further by suggesting that the word "ophir" is a corruption of "fura." He believes that the Biblical account of gold being brought to King Solomon from Ophir simply means that the gold was obtained from places in Africa known as "the diggings," just as we used to speak of the gold diggings in California or in Australia.

(3) NAMES REFERRING TO SOME NATURAL FEATURE SUCH AS COLOUR OR FORM OF THE GROUND.

Many minerals have a marked colour, and others are often associated with minerals having distinctive colours. This is particularly the case with mineral veins, of which iron pyrites is such a frequent component. The pyrites decomposes and gives rise to reddish-brown, yellowish-brown, or red minerals, which are likely to catch the eye even before there is any idea of mineral wealth underneath. Thus, for instance, a hill near Rossland, British Columbia, was called the "Red Mountain" before the discovery of the mines now so well known to the British public, namely, "Le Roi," "Centre Star," "War Eagle," etc. The soil was reddened by the ferruginous minerals formed by the decomposition of metallic sulphides containing iron. Another case may be taken from North Wales. Cae Coch, or the "Red Field," near Trefriw, where there is a large deposit of iron pyrites, no doubt received its name from the colour given to the soil by chalybeate springs, which issue from the ground near the deposit. Craig Goch, or "Red Rock," a name which is not uncommon for mines in Wales, denotes no doubt that the vein was discovered by a red ferruginous outcrop, and so does the name Fron Goch, or "Red Breast." The Red Mountain, near Birmingham, Alabama, owes its name to the outcrop of an important bed of iron ore. Sometimes it is a river which is coloured by ferruginous matter. In Wales we have the Afon-goch flowing down from the Parys mines, and in Spain there is the counterpart, but on a far larger scale, in the well-known Rio Tinto. In Hungary there are Veresviz and Verespatak, near Nágybánya, with the same meaning, and close at home you have the Red River at Camborne, though in this case the red-

ness is due to the suspended refuse from the dressing-floors of tin mines. An old copper mine near Dolgelly, whose name has become prominent of late years owing to trials with the Elmore process, is called Glasdir, meaning "Blue Ground." I consider it is highly probable that this name was given to the place on account of blue copper stains upon the rocks.

In the case of white we have an instance in the name of our own country, "Albion," from the colour of its cliffs.

In going from Moscow to Sebastopol a few weeks ago, I happened to notice that the form of ground presented that rolling surface with which we are so familiar in crossing the Chalk Downs, and I was not surprised shortly afterwards to see various chalk pits close to the railway station. The inference that I had made concerning the presence of chalk based upon the form of the ground was entirely correct. On asking my travelling companion the name of the town, I was told it was Bielgorod, which means "White Town." I may fairly hazard the suggestion that the name of the town is due to the white rocks upon which it is built.

The Smoky Mountains, in North Carolina, were called by the Indians Unaka, from their word "unakeh," meaning "white," because they obtained white kaolin from them.

In the ancient days European metal-mining was carried on mainly in the mountains, and this was so much the case that the Germans gave the name of "Bergmann," *i.e.* "hill man," "highlander," or "mountaineer," to the delver for ore, miners being generally known as the "Bergleute," or "hill people." Nowadays, of course, this appellation is not strictly correct, for mining is carried on as much in the flat country as in the hills; nevertheless the miner of the plains of Germany is still spoken of as the "hill man," and mining work generally is called "hill work" (Bergbau).

The site of a mineral deposit is often marked by an elevation, because the deposit is harder than the surrounding rocks, and has consequently suffered less from atmospheric weathering. It stands up, while the softer "country" has to a large extent been washed away. This fact is brought to our notice by the words

"hill," "mount," "knob," forming part of the names of scores of mines which might be cited, such as Broken Hill, Mount Morgan, Pilot Knob, etc.

(4) NAMES CONNECTED WITH DRESSING OR SMELTING OPERATIONS.

Those who have gone up the Val Anzasca to the foot of Monte Rosa may recollect the little village of Pestarena, with its gold mines. The working of gold dates back from very ancient days, and the village certainly received its name from grinding operations for the purpose of extracting the precious metal.

The fact that the Weald of Kent and Sussex was the scene of iron-working some centuries ago is made evident to us not only by the existence of mining pits, but also by such names as Furnace Wood, Furnace Farm, Furnace Plain, and Hammer Pond, pointing to smelting operations. The name Cinderford, in the Forest of Dean, tells the same story, though there the iron mining is not extinct, as it is in South-Eastern England.

The existence of gold and silver ores amongst the useful minerals of the Caucasus is indicated by such names as Okro Chana (Gold-smelting Works) in Georgian, and Gümisch Chana (Silver-smelting Works) in the Tartar tongue.

(5) IMMIGRATION OF FOREIGN PEOPLE.

From time to time in various countries the immigration of skilled miners has been encouraged. Some centuries ago the best ore miners were to be found in Saxony, and they were often invited by foreign potentates to investigate ore deposits and work them by improved methods. A river in Bosnia is named Saski Potok, or "Saxon River," from the fact that Saxon mining immigrants dwelt close to it. It is well known that Queen Elizabeth sent over to Germany for skilled miners, and we have evidence of their having dwelt among us by the words "sump" and "kibble," but I am not aware that any places are named after them in Cornwall.

Though my knowledge of foreign tongues and my opportunities of travel have not enabled me to do more than skim over my subject, I think it will be admitted that there is very often some

connection between place-names and mineral deposits. The matter seems to me one of interest in various ways. The miner may sometimes have his attention directed to the existence of valuable minerals by these names; to the geographer the question seems of special importance; whilst by following the lines I have indicated the historian may occasionally be reminded of facts which would otherwise escape his notice.

The President, on behalf of the Society, then presented the "William Bolitho" Gold Medal for 1902 to Dr. Richard Pearce. He said:—

Dr. Richard Pearce, I consider myself fortunate that my term of office as President should bring with it the gratifying duty of presenting you with the "William Bolitho" Gold Medal. There are many reasons why the task is specially pleasant to me. To begin with, we are old friends, and both old students of the Royal School of Mines. I had the pleasure of making your acquaintance as long ago as 1865, and I had met your father and obtained useful information from him several years before that. Secondly, you were predecessor in office as Lecturer of the Miners' Association of Cornwall and Devon. Thirdly, I welcome you as one who has done excellent scientific work on both sides of the Atlantic.

My list, which I fear is still incomplete, shows that you have written at least thirty-nine scientific papers and addresses. These give evidence of the wide field of your knowledge, as they deal not only with Geology and Mineralogy, but also with Chemistry and Metallurgy.

Your first paper, read in 1864, pointed out that mineral veins are not solely filled-up fissures, but are in many instances zones of altered rock. This view has since been generally accepted by geologists. It is unnecessary for me to enter into details concerning your scientific work, as the list which I have prepared gives the titles of your papers. I may sum up your work by saying that you have investigated a large number of comparatively rare minerals, and that you have given to the world much useful information concerning the genesis of ore deposits.

The fourth reason for congratulation is the fact that you have been able to combine eminence in science with much success in commercial metallurgical practice, and I cannot help suggesting that this is greatly due to your mastery of the scientific principles upon which such practice should always be based, and to your having been a pupil of such an illustrious teacher as the late Dr. Percy.

You have received honours in the United States. You were for two years President of the well-known American Institute of Mining Engineers, whose members are to be found in all countries, and you have also held office as President of the Colorado Scientific Society. No better proof of the esteem in which you are held across the water can be given than by mentioning the fact that you were the first person upon whom the Columbia College, of New York, conferred the Honorary Degree of Doctor of Philosophy. I feel sure that, had you been living on this side of the Atlantic, the award of the "William Bolitho" Medal would have been made to you earlier; but though it comes a little late, it will at all events show that the Royal Geological Society of Cornwall is anxious to record its appreciation of the excellent work which you have done in furthering the progress of science. I have very much pleasure in now handing to you the "William Bolitho" Gold Medal.

PAPERS, ETC., BY R. PEARCE, F.G.S.

TRANSACTIONS OF THE MINERS' ASSOCIATION, CORNWALL AND DEVON.

"The Influence of Lodes on Rocks." Read 1864.

TRANSACTIONS OF THE ROYAL GEOLOGICAL SOCIETY OF CORNWALL.

"Chrome Iron in the Lizard Serpentine." Read Oct., 1870. Vol. ix. p. 99.

"Pitchblende in Colorado." Read Oct., 1871. Vol. ix. p. 102.

"Pitchblende in Cornwall." Read Oct., 1871. Vol. ix. p. 103.

TRANSACTIONS OF THE COLORADO SCIENTIFIC SOCIETY.

"On the Estimation of Arsenic." Read Feb. 5, 1883. Vol. i.

"Occurrence of Tin in Cornwall." Read June 4, 1883. Vol. i.

Presidential Address. Read 1884. Vol. ii.

"Certain Interesting Crystalline Alloys." Read Feb. 2, 1885. Vol. ii.

"Further Investigation in the Formation of Crystalline Alloys." Read July 6, 1885. Vol. ii.

"New Occurrence of Copper Arseniates and Associated Minerals in Utah." Read 1885. Vol. ii.

"Goslarite in the Gagnon Mine." Read July, 1887. Vol. ii.

"A Mixture of Bornite and Stromeyerite." Read Oct. 17, 1887. Vol. ii.

"Pharmacosiderite from Utah." Vol. ii.

"Crystalline Compound of Arsenious and Sulphuric Acid." Read Feb. 3, 1890. Vol. iii.

"Furnace Products." Vol. iii.

"The Genesis of Ore Deposits." Vol. iii.

"Sublimed Tellurium." Vol. iii.

"Sesquisulphate of Iron in New Mexico." Vol. iii.

"A Specimen from Thirty-five Mines." Vol. iii.

"Tellurium and Bismuth in Sulphide Ores." Vol. iii.

"Informal Note on Tellurium and Bismuth." Vol. iii.

"Eruptive Dykes near Manchester, Mass." Read Nov. 6, 1893. Vol. iv.

"Gold in the Ores of Cripple Creek District." Read 1894. Vol. v.

"Tellurium in Oxidized Form with Gold." Read April 1, 1895. Vol. v.

"Uraninite in Colorado." Vol. v.

"A Silver and Gold Mineral containing Tellurium." Read Oct. 5, 1896. Vol. v.

"Tellurium in Oxide from Montana." Vol. v.

"Tellurium in Montana." Read 1897.

"Tellurium from Griffith Lode, Colorado."

"Tellurium in Gold Ore."

"Peculiar Occurrence of Tellurium and Vanadium in a Gold Ore from the Great Boulder Reef, Western Australia." Read Oct. 2, 1897. Vol. vi. p. 69.

"Occurrence of Rhodochrosite in the Original Mine, Butte City, Montana." Read Jan. 3, 1898. Vol. vi. p. 103.

"Occurrence of Selenium with Pyrite rich in Gold and Silver, and Remarks on a Gold Nugget from Montana."

TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS.

"Certain Crystalline Alloys." Read Feb., 1885. Vol. xiii. p. 738.

"Association of Minerals in the Gagnon Vein, Butte City, Montana." Read July, 1887. Vol. xvi. p. 62.

"On Tin Deposits in Cornwall." Read July, 1887. Vol. xvi. p. 57.

Presidential Address: "Progress of Metallurgical Science in the West." Read June, 1889. Vol. xviii. p. 55.

"Remarks on Hübnerite in Silver Ore." Read June, 1889. Vol. xviii. p. 248.

Presidential Address: "Observations on Gold Ores." Read Feb., 1890. Vol. xxi. p. 447.

REPORT OF THE COUNCIL

To the Annual General Meeting, November 4th, 1902.

THE Council report that the collections in the Society's Museums and Library, as well as the buildings themselves, are in good order, and believe that the members will admit that their property has been taken due care of during the past year.

The most difficult problem before them at present is caused by the want of room both in the Mineral Museum, but more especially in the Library, which continues to increase rapidly in size and value. This difficulty, which was staved off a year or two since by a trifling rearrangement, is now becoming serious, and requires a more drastic solution. The Council are loath to recommend the placing of bookshelves in the Museums or in the passage, but some such step will soon be compulsory.

The Museums have, as usual, been visited by a large number of people during the year.

His Royal Highness the Prince of Wales has been pleased to signify his intention of continuing the annual subscription of £20 which H.M. the King had granted out of the revenues of the Duchy of Cornwall to this Society.

The Council have received the following letter from the Royal Institution of Cornwall:—

"ROYAL INSTITUTION OF CORNWALL, TRURO,

"*August 2nd*, 1902.

"DEAR SIR,

"The Mining Association and Institute of Cornwall having failed last year to arrange for the usual Joint Meeting of Cornish Scientific Societies, which it was their turn to do, I have been

requested by the Council of this Institution to ask you to ascertain from the Council of the Royal Geological Society of Cornwall whether they consider that these meetings in the past have been sufficiently successful to warrant their continuance, and whether they desire that they should be continued.

"Yours very truly,

"EDWD. PARKYN, *Hon. Sec.*

"J. B. CORNISH, Esq."

—which they have considered, and refer to the members at this meeting.

As long ago as 1883 the late Dr. Barham wrote on behalf of the Royal Institution of Cornwall to this Society, suggesting an amalgamation or more intimate co-operation of the Cornish Societies, and although the proposal met with approval, it was not at that time followed up by any action.

At the Annual Meeting of this Society in October, 1891, Lord St. Levan, the President, following up a suggestion contained in a letter from Mr. T. B. Bolitho, spoke of a possible amalgamation into one county Society of the four leading scientific Societies of Cornwall, viz. the Royal Institution of Cornwall, the Royal Polytechnic Society, the Miners' Association and Mining Institute, and this Society. This proposal was laid before the other three Societies by your Council, and adopted in this modified form: "That a joint meeting of these Societies be convened each year in the several towns alternately." In accordance with this decision, the joint meetings have been held as follows:—

1893.	Truro . .	Royal Institution.
1894.	Penzance .	Royal Geological.
1895.	Camborne .	Miners' Association.
1896.	Falmouth .	Royal Polytechnic.
1897.	Camborne .	Miners' Association.
1898.	Truro . .	Royal Institution.
1899.	Penzance .	Royal Geological.
1900.	Falmouth .	Royal Polytechnic.

And, as has been shown by the letter quoted above, no meeting

has been held for the past two years, and the whole question is now reopened.

The Council, after careful consideration, do not see their way at present to recommend that the meetings be resuscitated.

The new Geological Survey of the county is being carried on by the officers of H.M. Survey, under the direction of Mr. Clement Reid, F.R.S., and special attention is being paid to the mining districts. After having collected information in the field, one of the officers is now engaged in examining the old mine plans preserved in London at the Home Office and transferring to the map many useful facts concerning the mineral veins of the county.

The Council have decided, taking advantage of the opportunity afforded by his presence in England, to award the "William Bolitho" Gold Medal for this year to Dr. Richard Pearce, of Denver, Colorado, U.S.A.

They recommend the election of Mr. W. A. E. Ussher, of H.M. Geological Survey, as an honorary member, in recognition of the services which this Society has received from such an experienced geologist.

LIBRARIAN'S REPORT

From November 1st, 1901, to October 31st, 1902.

THE Librarian acknowledges with thanks the following additions to the Library:—

Reconnaissances in the Cape Nome and Norton Bay Regions of Alaska in 1900. By A. H. Brooks, G. B. Richardson, A. J. Collier, and W. C. Mendenhall. Presented by the Authors.

Geology and Mineral Resources of the Copper River District of Alaska. By F. C. Schrader and A. C. Spencer. Presented by the Authors.

The Annual Report of the Geological Survey of Arkansas for 1892. By J. C. Branmer. Presented by the Author.

A Tentative List of the Flowering Plants known in Cornwall. By F. H. Davey. Presented by the Author.

Report on the Foraminifera of the Malay Archipelago. Part xi. By F. W. Millett. Presented by the Author.

TRANSACTIONS, REPORTS, ETC.

Adelaide. South Australian School of Mines.

Boston. American Academy of Arts and Sciences.

Bristol. Naturalists' Society.

Buenos Aires. Museo Nacional.

Canada Geological Survey.

——. Natural History Society of Montreal.

Cape of Good Hope. Department of Agriculture.

Cincinnati. Society of Natural History.

Denmark. Dansk Geologisk Forening Meddelelser.

Dorpat. Naturforscher Gesellschaft.

Dublin. Royal Dublin Society.

Freiberg. Department of Mines.
India. Geological Survey.
Indiana. Academy of Science.
Iowa. Geological Survey.
Japan. College of Science.
Kansas. Academy of Science.
Leicester. Literary and Philosophical Society.
——. Geological Association.
London. British Association.
——. Edinburgh and Dublin Philosophical Magazine.
——. Geological Society.
——. Geologists' Association.
——. Palæontographical Society.
——. Royal Society.
——. London and West Country Chamber of Mines.
Manchester. Geological Society.
——. Geographical Society.
——. Owens College, Museum.
Mexico. Instituto Geológico.
Minnesota. Academy of Natural Sciences.
Montana University.
Montevideo. Museo Nacional.
Netherlands-India. Mijnwezen in Nederlandsch Oost-Indië.
New South Wales. Royal Society.
——. Australasian Association for the Advancement of Science.
——. Department of Mines.
——. Geological Survey.
New York. American Geographical Society.
——. Academy of Sciences.
——. Museum of Natural History.
New Zealand. Department of Mines.
North of England Institute of Mining and Mechanical Engineers.
North Carolina. Elisha Mitchell Scientific Society.
Ohio. State University.
Philadelphia. Academy of Natural Sciences.
——. American Philosophical Society.
Pisa. Societá Toscana de Scienze Naturali.

Plymouth Institution.
Queensland. Department of Mines.
——. Department of Public Lands.
Truro. Royal Institution of Cornwall.
United States. Department of the Interior.
Victoria. Department of Mines.
Vienna. K. K. Geologischen Reichsanstalt.
——. K. K. Naturhistorischen Hofmuseums.
Western Australia. Geological Survey.

CURATOR'S REPORT.

DONATIONS TO THE MUSEUM.

NAME AND LOCALITY.	DONOR.
Soda porcellanite, from Lundy Beach Cliff, St. Minver (containing 9·35 soda, ·39 potash .	Howard Fox.
Shode, from St. Just	J. Ellis.

TREASURER'S STATEMENT, 1902.

Dr. *The Treasurer in Account with the Royal Geological Society of Cornwall.* **Cr.**

November 4th, 1902—	£	s.	d.
To Ordinary Subscriptions and Arrears	50	8	0
,, Subscription of His Royal Highness the Prince of Wales for the year 1901	20	0	0
,, Ditto ditto 1902	20	0	0
,, One Year's Dividend on £1,800 Midland Railway 2½% Debenture Stock, £45 0s. 0d., less tax, £2 13s. 5d.	42	6	7
,, Sale of *Transactions*	0	5	0
	£132	19	7
,, Balance due to Treasurer	60	7	2
	£193	6	9

November 4th, 1902—	£	s.	d.
By Balance from last year's Account	54	1	8
,, Rates and Taxes	0	8	0
,, Housekeeper's Salary	20	0	0
,, Curator's Salary	42	6	7
,, Fire Insurance Premium	2	12	9
,, Books, Binding, etc.	49	14	11
,, Coals, Gas, and Cleaning	8	6	1
,, Repairs to Buildings	2	16	7
,, Painting Exterior of Premises	6	7	0
,, Two Years' Subscriptions to Palæontographical Society	2	2	0
,, Sundry Expenses—Stationery, Advertising, etc.	4	11	2
	£193	6	9
,, Balance due to Treasurer	60	7	2

PENZANCE, *November 4th*, 1902.

T. R. BOLITHO, *Treasurer.*

W. BOLITHO GOLD MEDAL ACCOUNT.

Dr.	£	s.	d.	Cr.	£	s.	d.
November 1st, 1902—				November 13th, 1901—			
Garrard and Co.	12	10	0	By Balance	513	17	3
Balance	514	7	8	November 1st, 1902—			
				Interest to April 15th, 1902—	13	0	5
	£526	17	8		£526	17	8
				November 4th, 1902—			
				By Balance	514	7	8

LIST OF

PAPERS READ TO THE SOCIETY,

1902.

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1. President's Address. By C. Le Neve Foster, F.R.S.

2. Coast Sections in the Parish of St. Minver. By Howard Fox, F.G.S.

3. West of England Lead Deposits. By J. H. Collins, F.G.S.

4. Note on the "Faujasinæ" of the Tertiary Beds of St. Erth. By F. W. Millett, F.R.M.S.

SOME COAST SECTIONS IN THE PARISH OF ST. MINVER.

By Howard Fox, F.G.S.

Read November 4th, 1902.

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INTRODUCTION.

The scenery and other attractions of St. Minver are becoming so highly appreciated by visitors that a short, popular notice of the chief geological features of the most accessible of the coast sections north of the village of Rock may not be without interest.

This parish is divided into St. Minver Highlands and St. Minver Lowlands. It comprises a total of 8,733 acres, of which 1,000 are foreshore, including

the extensive sandbanks east of Padstow, the noted Doom Bar at the entrance of the Camel, and Polzeath Sands further north, which lie open to the waves of the Atlantic.

There are many miles of coast sections showing a series of beautifully variegated slates, purple, green, and buff, as well as the ordinary blue and grey slates of Devonian rocks. These variegated slates appear to be devoid of fossils, and have a general southerly dip with frequent reversals. There are numerous beds or dykes of igneous rocks, which are traced in an easterly and westerly direction. The slates adjoining these intrusive rocks are occasionally so altered by the contact as to resemble flint in structure, fracture, and weathering, and are technically described as being "porcellanised by contact metamorphism." The bold headland of Pentire Point, which is so conspicuous a feature of the landscape from miles around, as well as some other promontories, are composed of vesicular lavas, while Pentire cliffs and the promontory further east, on which Cliff Castle entrenchments are seen, convey the impression of basaltic structure and of extinct volcanoes.

AUTHORITIES.

The most important references by geologists to this region appear to be the following.

Sir Henry De la Beche, in his Report on the Geology of Cornwall, Devon, and West Somerset, published in 1839, at page 88, writes :—

"Numerous bands of greenstone and other trappean rocks are found in the strike of the beds from Pentire Point and Hell Bay through Endellyon and Port Isaac eastward. Some of these bands are formed of greenstone, some of varieties to which it is, as usual, difficult to assign names, while others are vesicular, the vesicles being frequently filled by carbonate of lime, an interesting fact, inasmuch as it would appear to show calcareous matter disseminated through the associated mass. These rocks are found between Endellyon and Port Isaac. While some of the trap rocks, more particularly the vesicular varieties, remind us of the contemporaneous igneous products, so often previously noticed, others break through the slates in a manner to show that the latter were consolidated before the igneous matter was intruded among them. Examples of intrusion are well exhibited near Porthqueen, and at Kellan Head fragments of slate are caught up in the trap, where they have apparently been much altered by their imprisonment in the igneous mass. There is, however, notwithstanding the clear intrusion of part of the trap, so much vesicular rock in some places that we might consider igneous rocks to have flowed during the general deposit of the accompanying sedimentary beds."

In the seventh volume of your *Transactions* Mr. Nicholas Whitley writes, at page 221 :—

"Further east Pentire Head is almost wholly

Plutonic, being the best defined region of ancient volcanoes in the county."

Mr. J. Arthur Phillips, in his paper, "On the so-called 'Greenstones' of Central and Eastern Cornwall," published 1873 in the *Quarterly Journal of the Geological Society*, vol. xxxiv., writes, at page 476:—

"The rocks in this [central northern] district, marked in the Survey Map as 'Greenstones,' belong to at least three distinct classes—namely, crystalline pyroxenic rocks, vesicular lavas, and foliated ash-beds."

Under "Blue Elvans" he classes "a dark green trap, which at Pentire Point is interbedded with the vesicular lavas," and gives an analysis of this trap at page 477 and a microscopic section of this lava in Plate XX., Fig. 2; while at page 482 he gives analyses of the lavas at Pentire Head and Port Isaac. At page 478 he gives a microscopic description of a "crystalline rock in the parish of St. Minver," and in Plate XXII., Fig. 5, a coloured microscopic section of the same.

ROCK.

The most convenient way of reaching this district is by road from Wadebridge, or by ferry from Padstow to the village of Rock.[1]

[1] The visitor should have with him three of the 6-inch-to-the-mile Ordnance Maps, Cornwall, Nos. 18 N.E., 18 S.E., 19 N.W.; obtainable through any bookseller or from the post offices of most towns at 1*s.* each.

If we decide to go by the ferry, it is advisable to do so about high-water, or during the flood tide, because the sand on the northern side of the river is often, during the ebb tide, soft and fatiguing to pedestrians. Immediately to the eastward of Crane Quay, Rock, and along the shores of Porthilly Cove, there are a series of limestone beds and slates with a general southerly dip, veins of calcite, sand consolidated with calcareous cement, and several exposures of intrusive igneous rock. There are also some fossiliferous slates. We only propose to deal with the coast sections north of Rock in this paper.

The map of the Geological Survey is based on the work of Sir Henry De la Beche. It shows a bed of limestone and two igneous beds north of the village of Rock. A well is now being sunk in the first field we enter when going from the village to the golf links, and this well cuts through the limestone bed. Quarries have been opened in the sand-hills on both the igneous beds, which are very conspicuous from the Padstow side of the river.

ROCK QUARRY.

This quarry is about a quarter of a mile west from Rock village. The rock is crystalline and fresh, varies from fine- to coarse-grained, and is veined with quartz and calcite. It is a doleritic camptonite.

An old engine-house stands outside the southern division of this quarry, and the walls on either side as we enter show blocks of bluish, green-grey,

glossy, very brittle rock, which is the slate of the district altered by contact metamorphism. When we reach the quarry we find on the right hand, *i.e.* the eastern side, several of these indurated beds of slate interbedded with limestone and the greenstone, which is here fine-grained and bluish grey in colour, all having a southerly dip of 45°. The greenstone in the centre of the quarry is coarser grained and darker in colour.

In the upper part of this quarry, which is most easily reached from above, a bed of this indurated slate, from 2 to 3 feet thick, is seen to weather white in places, and a bed of the same indurated slate, 6 inches thick, in the greenstone beds of the east end of this upper shelf, dipping 45° south, has a shining black appearance, which after rain resembles pitch-stone. The northern division of this quarry shows a coarse-grained crystalline rock, used for road metal.

Mr. John Parkinson, F.G.S., of Cambridge, has most kindly examined specimens and microscopic slices of this rock (specimens 690, *a* and *b*), and his notes of these and of others mentioned hereafter will be found at the end of this paper.

A quarry of slate lies north of Rock, near the first tee of the golf links, at the north end of which a fold of indurated slate can be seen, indicating the proximity of an igneous rock.

CASSOCK HILL QUARRY.

About 300 yards north of Rock Quarry we come to another quarry in the sand-hills, at the S.W. foot of a rise named Cassock Hill. The greenstone here is light bluish grey in colour, medium-grained, crystalline, and weathers the usual rusty colour (specimen 691). A thin bed of indurated slate is seen in the greenstone on the eastern margin.

On leaving this quarry we walk along a path in the sand-hills close to the shore, and find ourselves for some distance in a little forest of Portland Spurge (*Euphorbia Portlandica*), which in autumn attains a height of from 1½ to 2 feet.

When we are about half-way to a house in the distance, called Bray Cottage, we descend to the foreshore over dark blue slates, and just before reaching the greenstone, which forms Bray Hill, we may, by looking back towards the south, notice a conspicuous light brown bed or dyke of igneous rock (specimen 692), from 4 to 5 feet in thickness, amongst the slate, adjoining a fault marked by a cave at its base. A tongue of this dyke appears to intrude in the slate above the main bed, and close to the sandy foreshore the dyke is faulted down half its width. It is a medium-grained crystalline rock with black specks, and weathers brown and grey. A light bluish green slate occupies the northern side of this cave and fault in the cliff.

BRAY HILL.

If the tide permits, we now walk along the shore to the west of this hill, and examine the two beds of greenstone indicated in the Survey Map. Beds of consolidated sand are often laid bare on the shore, and the junction of the slates with the first bed is marked by two caves at the base of a fault which is partially filled with calcareous deposits. The slate dips southerly, and is not much altered in structure. The greenstone is much weathered, and extends for some 30 yards along the coast. It is succeeded by slate and greenstone, more or less intermixed, for another 30 yards, when an igneous rock of coarse grain forms the cliff for the next 100 yards, and becomes disjointed in large boulders, which strew the foreshore.

On the north boundary of this mass we see in immediate contact with it porcellanised slate from 2 to 3 feet in thickness, weathering white in places. The purple and green slates now occupy the coast for the next two miles. Soon after rounding the point of Bray Hill, and turning eastward, we see at the top of the cliff some beds of purple slate folded over themselves, and faulted against a greenish slate much veined with quartz. When we reach the end of the rocks along the foreshore we skirt the hill till we reach a quarry on its eastern face. The rock is fine-grained and greenish. Mr. Parkinson says it is greatly altered, without definite characters; some small grains of quartz

are probably original. The hand specimens resemble varieties of 693.

The slate in contact with this greenstone is somewhat indurated. The top of Bray Hill is 200 feet above sea-level, and both igneous and sedimentary rocks appear through its surface, both more or less altered, the igneous being a coarse-grained crystalline rock, resembling the Rock Quarry stone 690.

ST. ENODOC CHURCH.

Two hundred yards east of Bray Hill Quarry we see St. Enodoc Church, called locally "Sinkineddy," built 1470 A.D., originally a chapel-of-ease dedicated to St. Enodoc or St. Gwinnodock, to supply the place of an ancient oratory. This church has been more or less buried in blown sand, so that at one period the clergyman and clerk had to enter by a window to hold an occasional service, in order to maintain their privileges. The sand is now turfed over, and its further shifting arrested.

We now cross the sand of Daymer Bay, the site of a submarine forest, which, like some others on the coast of Cornwall, is only exposed to view after violent storms have shifted the sand. On our left is

DOOM BAR,

where so many vessels have been wrecked when trying to seek shelter in Padstow Harbour.

Murray's *Handbook for Devon and Cornwall* has the following reference to this bar (edit. 1863,

p. 215): "Dunbar (Dune Bar). The sands are thought to be now on the decrease, owing to the amazing quantity which is annually taken from the Dunbar and despatched for manure up the country. They are said to be the richest in the county in carbonate of lime, of which they contain 80 per cent., and are in such demand that the amount thus carried away in the year has been estimated at no less than 100,000 tons." This bar is now (1902) considered to be somewhat lower than it was formerly, but to have spread out more, and to have contracted the narrow channel between it and the cliffs to the west, and also to have reduced the water in Hawker's Cove from 13 to 9 feet at low tide. A certain amount of sand is taken annually from it as ballast for vessels, and some cargoes are sent to Bristol for building purposes. The entire amount taken now from this bar, and from the various sand-banks higher up the river, for agricultural purposes, for ballast, and for building, is not estimated at more than 20,000 tons per annum. We now approach

TREBETHERICK[1] POINT,

and can walk on the top of the low cliff, or over the variegated and somewhat disturbed beds of slate which form the foreshore, until we reach this point. As we round the Point we find the beds of slate disordered, with a general northerly dip. From this to Greenaway Beach, some quarter of a mile

[1] Trebetherick, the town or farm place of St. Petherick (Bannister).

FIG. 1. TREBETHERICK SAND CLIFF.

To face p. 659.

distant, we shall find it interesting to walk under the cliff, which for the next 300 yards, with small exception, is composed of sand, and in places is 40–50 feet high. Below the sandy soil at the top of the cliff is seen the raised beach marked on the Survey Map. It is 8 feet deep in some places, and is crowded with angular and rounded pieces of quartz and slate, as well as blocks of consolidated sand. The quartz pebbles vary from 1 to 12 inches in diameter, and the foreshore and grassy slopes of the cliffs are strewn with the pebbles that have fallen from above. Among them is a flint pebble 14 inches long, by 10 thick and 9 broad. An old cannon lies half-way down one of the recesses, as if it had been tumbled over the cliff. About 200 yards from Trebetherick Point a cart road has been cut, through these variegated slates and a partially consolidated corner of sand cliff, to the beach. In this cutting we see an excellent example of the elbows formed by the folding of the beds, and broken edges of slate are crushed into a zigzag immediately north of the folds. We have now reached a cliff about 40 feet high, almost entirely composed of sand, and here, as elsewhere in this district, thin parallel ridges of sand, consolidated by calcareous cement, stand conspicuously out of the mass of sand. Fig. 1 is from a photograph taken from the point where the cart road reaches the beach, looking north, and gives some idea of this sand cliff. The subsoil has numerous land shells embedded in it. There are several exposures of intrusive rocks in this neigh-

bourhood, vesicular, amygdaloidal, schistose, studded with crystals of calcite, and much weathered. The most interesting is a bed 8 feet thick at the south end of Greenaway Beach. It is probably one of the two marked on the Survey Map, although not exactly in the position there indicated. It is very conspicuous, as it weathers in bold masses at the base of the cliff and along the foreshore, and huge blocks disjointed from it strew the beach. It dips west of north 35°–40°, and lies conformably with the variegated slates, which are crushed into thin laminæ, but otherwise not perceptibly altered by the contact. The rock (specimen 693) is fine- to medium-grained crystalline, greyish in colour, with black flakes occasionally squeezed or pulled out into long pieces, and is full of vesicles filled with quartz or calcite. Some fragments of slate involved in its substance are porcellanised. It is very schistose in places, and weathers a brownish purple. The slates on the foreshore between Trebetherick Point and Greenaway Beach show in certain places a scaly, lenticular, or oyster-shell structure, and in others are weathered in small, crowded circles, the size of peas, resembling the scales or plates on the skin of some reptiles. This is probably due to pressure from earth movements.

GREENAWAY BEACH.

This beach is composed of shingle, varying from coarse to very fine, and even approaching coarse sand. It also contains shell fragments. The rocks

of the foreshore have a reversed or northerly dip, and at the north end of the beach there is a conspicuous fault, and huge blocks of quartz and slate breccia in a siliceous matrix, with quartz veins weathering out in reticulations, lie scattered about the beach and the rocks of the foreshore. A large mass of igneous rock is seen *in situ* close to the northern cliff, and is traced to its base. It weathers in some places so as to resemble porphyritic diorite, but in reality it is an amygdaloidal rock, with black and white spots, in a bluish green magma.

The purple and green slates occupy the coast from here to the village of Polzeath. The visitor, unless fond of climbing, should now retrace his steps until he can ascend the cliff and walk along its top to Polzeath. It is quite practicable to proceed by the rocks at low-water spring tides. If we take this course we soon reach

BROADAGOGUE COVE.

Underneath the overhanging rocks on the south side of this beach there are many square yards of closely built sand-tubes, the home of colonies of Sabellaria. We find the same on many sand beaches south of the Camel. This beach is about 150 yards in width, and contains many flint pebbles.

Beyond this beach we walk over rocks at first dotted and then, in October, completely covered with mussels. In one place the hard purple slate is worn by the sea into curved, intricate channels, as if there had been originally a series of potholes,

and these had subsequently been opened into and connected with each other. We did not identify any further igneous rock, though the Survey Map indicates one on this part of the coast; but we found one due east of this on either side the cart road leading from Polzeath sands to Trebetherick Farm. This bed is about 10 feet wide, of a greenish colour, and much weathered, about 150 yards from the bottom of the hill.

POLZEATH[1] QUARRY.

At the north end of Polzeath village a quarry has been opened in a bed of igneous rock, not marked on the Survey Map, but so extensive as to form the ridge of the hill behind it. The rock (specimen 695) is compact, greenish in colour, with black spots, and is much veined with quartz and calcite. The slates adjoining are not much altered, though a thin white coating on the greenstone at the north side of the entrance appears to be porcellanised slate. A second quarry higher up on the hill yielded more weathered stones, used for hedging purposes.

POLZEATH SANDS.

After leaving the lower quarry we walk along the sand at the base of the low cliff, and soon reach a foot descent from above. Immediately north of this descent a fissure quartz vein, 2 to 3 inches wide, exposes some good crystals, and 70 yards

[1] Polzeath, dry pit; Pr. (?) pool of the arrow (seth), or by the seat (*ased'n*) (Bannister).

further north, after passing a tunnel excavated on a mineral lode, from which excellent drinking-water is always running, we see another fissure quartz extending to the top of the cliff, full of cavities or "druses," showing crystals of various colours, and some beautifully radiated quartz surmounted by caps of coloured quartz crystals.

The purple, green, grey, and buff slates of the cliffs are contorted with numerous reverse dips and much veined with quartz and calcite. We see repeated faults marked by caverns at their foot, one of which, about 60 yards before reaching the Steps in Cockett Haven, exposes a fault breccia. In the cavern, 20 yards east of these Steps, we find the sides of the extreme end of a cave covered with a siliceous deposit, or sinter, which at the base of the west side nearer the entrance is 1½ inches thick.

PENTIRE GLAZE MINE.

If we leave the sands for a few minutes and mount the Steps we shall find, about 300 yards north of them, on the way to Pentire Glaze Farm, an old mine shaft connected with an adit which opens into the south side of Pentire Glaze Valley, and among the refuse quartz lying about we may meet with crystals of silver-lead, copper, etc. Mr. William Jory Henwood, F.R.S., in your eighth volume of *Transactions*, at page 120, gives in a note a table of twenty-seven mines, in which the proportion of silver in Cornish lead ores is re-

corded from the mineral statistics of the Geological Survey compiled by Mr. Hunt. This table places Pentire Glaze Mine eleventh in the scale of richness, producing over twenty-two ounces of silver to the ton of lead ore.

Returning to the Steps and passing along the sands of Slipper Point to Pentire Glaze Haven, and continuing along the foot of the cliffs, we reach Pentire Haven, where we say good-bye to the variegated slates. This cove, of which we annex a map, is locally called "Pentire Haun," and is spelt in the parish map at the Vicarage "Hone," and is itself probably the result of an extensive fault.

PENTIRE HAVEN.

This is an extremely interesting spot. On the east side of the haven two exposures of intrusive igneous rocks not marked on the Survey Map are seen in the cliff within 10 feet of each other, the southern one about 8 feet wide, the other about 18 inches wide. They have left recesses in the cliff, owing to both large and small blocks having become disjointed from the parent mass. These blocks lie about the foreshore as boulders and large pebbles. They weather a dark brown or black in the cliff above, and pale bluish grey below in the scour of the sand; they are much veined with quartz. The rock (specimen 696), when fractured, shows a fine-grained crystalline rock, bluish grey in colour, speckled with small patches apparently of chlorite, reminding Mr. Parkinson of pseudomorphs rather

than amygdaloids. It is apparently related to the Cassock Hill rock (specimen 691).

The slate beds adjoining are tilted at a high angle, and do not appear to be much altered, although fragments of slate involved in the igneous mass become indurated. To the north of these igneous beds is a cave at the base of a fault.

The rocks on the west side of the haven give evidence of great disruption and pressure from earth movements. Immediately below a stone wall which descends close to the top of the cliff, a bed of igneous rock is seen to be much discoloured above and fairly fresh underneath the sand. It becomes divided, and one branch forms the ridge of the hill. It may owe its origin to a branch of the eastern bed (No. 696) being faulted north, as it appears to be similar in composition, though more schistose. A calcite breccia is seen in the slate close to the north base of this bed. When storms have removed the sand from this haven, the two igneous beds of the eastern cliff appear to unite in the floor of the haven, and can be traced in an almost perpendicular dip, more or less interbedded with slate, towards the base of the seaward portion of the western cliff. The scour of the sand has rounded the exposed edges of both igneous and sedimentary rocks, which become disjointed, and soon become worn into the form of long pebbles. The outer cliff of the western side of this haven deserves careful examination. In the lower part of the cliff we not only see igneous rock

similar to No. 696, but a variety of structure, including a dark basic band from 1 to 2 inches thick, and below this, massive vesicular weathered decomposing rock resembling lava. Pebbles of igneous rock (specimen 697*b*) up to 12 inches in their long diameter are seen embedded in the slates of the foreshore, as well as lenticular pieces in definite horizons, as if originating from the same igneous bed. Apparently here we have representatives not only of the exceedingly amygdaloidal type, but of the more compact dyke rock of the eastern side of the haven. The evidences of pressure are such as to suggest that the pebble-like masses are in reality but the disjointed fragments of a once continuous dyke or flow. In the upper part of this cliff, which we ascend from the haven, we see a conglomerate of small brown pebbles in slate similar to a conglomerate we shall find round the Point at the "Gravel Caverns." Some of this rust-coloured igneous rock in the upper part of the cliff weathers in rounded forms, so as to resemble, at a distance, a large-pebble conglomerate. The basic band can be traced with the more acid rock until they disappear with a crush conglomerate in the top of the cliff, their further progress being concealed by the projecting point and the soil and vegetation on the top, but reappearing, we believe, in a somewhat altered form and fresher structure in the "Gravel Caverns" further west. Near the point where this crush conglomerate disappears in the

cliff we also find a dark siliceous friction breccia containing fragments of slate.

A fault is seen, when the sand is sufficiently removed, to run at the base of the seaward portion of the western cliff in a westerly direction, and we do not find any of the variegated purple and green slates north of this fault or of this igneous bed. To the north of this fault we find blue and grey slates, which in some few places yield fossils, most of which are not sufficiently well preserved to be determinable.

TAR CAVERN.

About 70 yards due west of Pentire Haven there is a recess in the cliff to which the name of Tar Cavern is given on the map. There is no indication of any cavern now; the roof must first have fallen in, as so often happens on this coast, and the arch must have followed suit. What we see is a fault which is conspicuous in the cliff dipping north and which runs in the direction of Gulland Island along the foreshore, say W. by S. The southern side of this fault shows in the cliff a slickenside coloured green from copper, and in the north cliff a bed of black, consolidated sand about 12 inches deep is seen between the subsoil and the broken edges of the rocks. The black colour of this bed has been determined by Mr. B. Kitto, F.C.S., to be due to oxide of manganese. Some rust-coloured decomposed pebbles lie in and below this black band of sand. A trench runs in a W.S.W. direction

from this recess, where boulders and pebbles of igneous rock are embedded in slate. Igneous rock *in situ* appears also in the bottom of the trench as well as loose boulders of igneous rock here and there, both south and west of it. About 30 yards south of this Tar Cavern recess an igneous bed is faulted north, and takes a more westerly direction than at first. A large rounded block (specimen 697*c*) in this bed weathers in small white projections similar to a fragment in a fault breccia shortly to be described, and in composition resembling the pebble (specimen 697*b*). We next round the Point, and after crossing some other minor faults we reach a series of caves named on the map

GRAVEL CAVERNS.

At the back of the first beach are two caves. The right-hand or southern one shows, on its northern side, a fault breccia in which igneous and sedimentary rocks appear. No. 697*a* is a fragment of an igneous rock which weathers in small prominences resembling pisolite, and in composition is similar to 697*b* and 697*c*. The northern cave is at the foot of a fault, and exposes a breccia consisting of fragments of slate cemented by calcite and dolomite with magnetite, and a huge boulder embedded in slate, too much altered to show definite characters under the microscope. A derrick is seen at the top of the cliff, by means of which the shingle is raised and carried away by carts. The pebbles forming the shingle are very bright in colour, and

consist of black and other flints, white and coloured quartz, variously coloured greenstones, and indurated slate. Three large blocks of conglomerate, conspicuous from their thickly set enclosed small pebbles, lie immediately seaward of this northern cavern of beach No. 1.

A second beach lies to the north with a large cave behind it, the roof of which is rich in *Asplenium marinum*, as are many of the caves and innumerable recesses in the rocky sea slopes of this district. Twenty yards seaward of this cave we see beds of slate *in situ* thickly dotted with small pebbles such as we found in the western outer cliff of Pentire Haven, and overlying these conglomerates are beds of bluish slate, in which we found fossil fragments of crinoids and indications of other organic remains. The slate beds dip a little west of north at a low angle. Proceeding northward, in climbing on to a ledge at the base of the cliff, we find our right hand resting on a bed of the same small-pebble conglomerate, which owes its elevation to a fault clearly seen at the foot of the cliff. Boulders of conglomerate with calcareous matrix and abundance of iron pyrites are also strewn about with igneous boulders. After crossing further faults we find embedded in the slates, about 70 yards north of the Gravel Caverns, compact pebble-like bodies, 9–12 inches long, with a radiated margin of half an inch or more (No. 698), and a puckered thin bed of the same nature running along the foreshore and up the cliff within a few inches of the

former. These pebble-like bodies, which Mr. Parkinson thinks are concretions, are generally lying with their long axes parallel with the cleavage of the slates. In another 70 or 80 yards we come on a very conspicuous fault running east and west, the fissure being filled with quartz cavities and "druses," in which some beautiful crystals may be studied. Beyond this quartz fissure several minor faults are crossed, one with a cave at its base in the cliff, a crush breccia is seen in the foreshore, and by the side and at the head of a gully which approaches the foot of the cliff we find more pebbles with radiated margins similar to No. 698, some of which are embedded with their long axes across the structure of the slate, *i.e.* at right angles to the cleavage. Some of the slates on the foreshore weather in scaly lenticular structure resembling crocodile-skin, as in the Trebetherick rocks. On passing a footway to the top of the low cliff we see an indication of a raised beach in consolidated black sand, beyond which a deep gully cuts us off from further progress under the cliffs. The cliff at the head of this gully is covered with plants of the Sea Lavender (*Statice auriculæfolia*).

The next accessible place of interest is

PENTIRE POINT,

256 feet above sea-level, to reach which we must ascend the cliff, and to avoid an inconveniently steep slope it is advisable to walk somewhat inland and approach it from the tableland at top. The

FIG. 4. SPHERULITIC STRUCTURE, PENTIRE CLIFF.

To face p. 671.

FIG. 3. PENTIRE CLIFF.

To face p. 671.

FIG. 2. CLIFF CASTLE PROMONTORY.

To face p. 671.

headland and cliffs of Pentire Point and thence westward are composed of vesicular lavas, and repay careful exploration. Fig. 2 is a view of Cliff Castle promontory, with its hills and necks of lateral cones reminding us of extinct volcanoes. King Arthur's Castle at Tintagel on a clear day would be visible in the distance. Fig. 3 shows the top of a cliff, from the lower part of which there is a perpendicular face or slickenside of 100 feet or more, "sheared, as it were," to use the words of Ruskin, "by a daring sword sweep." Fig. 4 gives a faint indication of the spheroidal structure which is very frequent through all this range of cliff. The surfaces of many of the exposures facing seawards are crowded with this spheroidal structure, recalling the same feature so conspicuous in the Tertiary basalts of the Giant's Causeway; but these Pentire lavas (No. 699), from their more venerable age, are more weathered, and subsequent earth movements have in many instances apparently squeezed the original circular concentric structure into ellipses and even open loops. Indurated dark slate (No. 700) is seen in the lava, as if earth movements had squeezed it into and around the spheroidal masses.

When we have thoroughly examined and clambered about the promontory on which Cliff Castle stands with its series of trenches and raised defence works, behind which our prehistoric British natives are supposed to have sought refuge when hard pressed by their enemies, we resume our walk round the coast, keeping to the seaward side of a

stone wall until we reach a dip in the land, covered with bracken and gorse, 300 yards north of Pentire Farm. This dip leads us to one of the few practicable descents in this promontory to a beach which is not favoured with a name in either of the Ordnance parish maps, but which we will call

COM BEACH,

as it is immediately west of Com Head, and is locally known as Com Pit. This beach is divided by a small promontory at high water into two distinct coves with caves in each. At low water there is one beach in common, and we can crawl through a low cave which runs through the base of the promontory from one beach to the other. We can study here the association of igneous and sedimentary rocks. Our friend Mr. Alexander Somervail drew our attention to a bed of fossiliferous grey slate on the north side of the northern beach, but the only determinable organism was a fragment of the ubiquitous crinoid showing good structure.

Returning to the top of the cliff, we cross over Com Head, 247 feet above sea-level, with the muzzle of a half-buried cannon at its summit, pointing to the zenith, and in about half a mile come to large piles of prepared and refuse greenstone adjoining

PENTIRE GLAZE QUARRY,

about 600 yards east-north-east of Pentire Glaze Farm. The stone (specimen 701) from this quarry

is used for building the new houses overlooking Polzeath Sands, on the Pentire Glaze Estate. It contains both coarse- and fine-grained crystalline rock. This greenstone is bluish grey and compact, with numerous black specks and occasionally with greenish enclosures; it weathers a rusty colour, as do most of the igneous rocks in this district, and is bedded with a southerly dip of 55°–60°. The slate on the floor of the quarry is indurated, but on the northern boundary not much altered, while a thin coating of porcellanised slate is seen in a few places overlying the greenstone. Half a mile east of this quarry the path leads us to a precipice, over which we look down on a small cove called in the map Markham's Quay, and when the tide is low we may notice a bed, from 2 to 3 feet wide, of light green igneous rock in the slates of the foreshore at the base of the cliff on the west side.

LUNDY HOLE.

About 250 yards east of Markham's Quay we reach Lundy Hole. We stand on the edge of a perpendicular cliff of greenstone, from which fresh specimens may be broken. The rock resembles that of Cassock Hill Quarry (No. 691). When the tide is high and the sea rough we look into a cauldron of foam and turmoil. The arch under which the sea enters is composed of slate. Immediately east of this we come to

LUNDY BEACH.

This is a very picturesque spot, especially at low tide, when numerous caves may be explored, and a sandy beach favours bathing. We find here the most interesting examples of contact metamorphism north of the Camel. As we approach it from Lundy Hole, we notice a whitish piece of cliff on the western side, which we reach by a slight descent. The slate here is so altered as to resemble chert or flint in weathering and structure. It breaks with a conchoidal fracture, varies in colour from creamy grey to light brown and dark grey, and weathers white (specimen 704). It closely resembles the soda-felspar rock of Dinas Head, in the parish of St. Merryn, south of the Camel, described by Mr. Teall, F.R.S.,[1] and Lieut.-General McMahon, F.R.S.[2] Fig. 5 is from a photograph of a portion of this porcellanised slate, which can be examined at any state of tide. The foreshore contains rocks which show stages of transformation from the normal slate to this porcellanite.

The soda-felspar rock of Dinas Head was found by Mr. J. H. Player, F.C.S., to contain 9·8 per cent of soda and ·7 of potash. This rock of Lundy Beach cliff has been determined by Mr. B. Kitto, F.C.S., to contain 9·35 of soda and ·39 of potash. General McMahon records his reasons in his notes for

[1] *Geol. Mag.*, Jan., 1895.
[2] *Trans. Roy. Geol. Soc. Corn.*, vol. xi. pp. 708-14.

FIG. 5. PORCELLANISED SLATE AT LUNDY BEACH.

To face p. 674.

considering the Dinas Head stone to be an altered sedimentary rock, which he says may be called a "porcellanite," notwithstanding that in one place on Dinas Head it assumed a nodular form showing spherulitic structure. The analysis of this Lundy Beach stone confirms the view that the Dinas Head rock and those resembling it at Cataclews, Round Hole Point, Rock, Bray Hill, Lundy Beach, etc., are all porcellanites or adinoles.[1] Mr. Parkinson examined an interesting greenish-white spotted slate (No. 702) and a pale yellow or grey altered slate (No. 703) from the west side of the beach, some 12 feet from the nearest visible igneous rock, and gives the results in his notes. The greenstone (specimen 705) of Lundy Beach is medium-grained, greenish with white and black spots, and occasionally schistose.

When we leave Lundy Beach we ascend 100 feet, passing a tunnel excavated for mining purposes, in which bats occasionally take refuge by day. We cross the top of Pennywilgie Point, and immediately descend into the adjoining valley which terminates in Epphaven Cove ("Hip Hone" of the parish map at the Vicarage), where the slate dips to the south below the igneous rock and is not much affected by the contact. As we approach the valley from above we notice quartz veining the dark slates of the eastern cliffs of this cove in a very conspicuous manner. On the foreshore we find many quartz pebbles. The igneous rock has larger

[1] *Vide British Petrology*, by Teall, pp. 217–19.

crystals than the Lundy Beach rock, and some of the beds are porphyritic. Some boulders weathering a reddish brown are composed of very fine-grained light grey crystalline rock with large vesicles and cavities filled with quartz. There are many large caves in the west cliffs. On quitting this cove we continue our coast walk and mount 220 feet to the summit of the bold headland of Trevan Point, passing, when half-way up the ascent, a small quarry on the right, in which we see indurated fragments of slate in the igneous rock. On the south side of the extreme summit another small quarry shows beds of indurated slate which weathers a blackish blue among the vesicular lavas of which this headland, like that of Pentire Point, is composed. Another three-quarters of a mile brings us to Port Quin, the stream in the centre of which is the eastern boundary of St. Minver parish.

The visitor having reached Port Quin should not fail to enter the parish of St. Endellion and examine the white-weathered porcellanised slate in the greenstone cliffs on the eastern side of Kellan Head, described by De la Beche.

MR. JOHN PARKINSON'S NOTES.

690*a*. Rock Quarry.

A FAIRLY coarse compound of augite and plagioclase, possibly some original hornblende, with ilmenite and apatite as abundant accessory minerals. The augite has crystallised before the plagioclase, but the difference in time was probably not great. It exhibits also the alter-

ation into a red-brown hornblende. The rock—a doleritic camptonite—is practically identical with that figured and described by J. A. Phillips (*Q.J.G.S.*, vol. xxxiv., plate 22, fig. 5, p. 478). In the coarser varieties the two principal constituents are plainly visible to the naked eye.

690b.

The rock of finer grain near the quarry border consists of lath-shaped crystals of red-brown hornblende, doubtless in many cases replacing augite, but in others primary, for well-formed cross-sections are fairly frequent. Small and irregular flakes of brown mica are not uncommon, and some green pseudomorphs may represent original olivine. As far as the somewhat decomposed state of the rock admits of determination, a rather acid plagioclase is the predominant felspar. Ilmenite grains are common, usually altered to leucoxene. Secondary carbonates occur in patches and veins. The rock is a camptonite. Mr. G. T. Prior, M.A., of South Kensington, kindly examined the slide, and agreed in the lamprophyric characters. Both *690b* and *690a* may be compared with the Warwickshire camptonites.

691. Cassock Hill Quarry.

The thin section contains an opaque felspar, probably a rather basic plagioclase; an idiomorphic, almost opaque, brownish mineral acting slightly on one nicol, which, I think, may be altered augite, and apparently pseudomorphs after olivine. Apatite and ilmenite are accessory minerals. Closely related to *690a*.

692. Bray Hill, 5 ft., S. Bed. Bray Cottage.

Closely resembles 701 (Pentire Glaze Quarry). Elongated crystals of a ferromagnesian mineral, now fibrous and greatly altered, are the most conspicuous constituents. At first sight they resemble an altered mica, but since cross-sections of hornblende occur, part at least

must be referred to this mineral. The remainder of the slide consists of lath-shaped felspars, too altered for determination, and some interstitial quartz which may be secondary. The slide also contains a few semi-porphyritic felspars, up to ·04 inch in length, and needles of apatite. This rock is a lamprophyre.

693. TREBETHERICK, 8 FT. BED.

A fine-grained, greenish-grey rock, commonly without recognisable minerals, but frequently containing ovoid green spots of chlorite. Two thin sections have been prepared. The first is too decomposed for determination: porphyritic felspars were probably an original character, needles of apatite are rather common, and an opaque mineral, which is abundant, is probably derived, at least in part, from ilmenite.

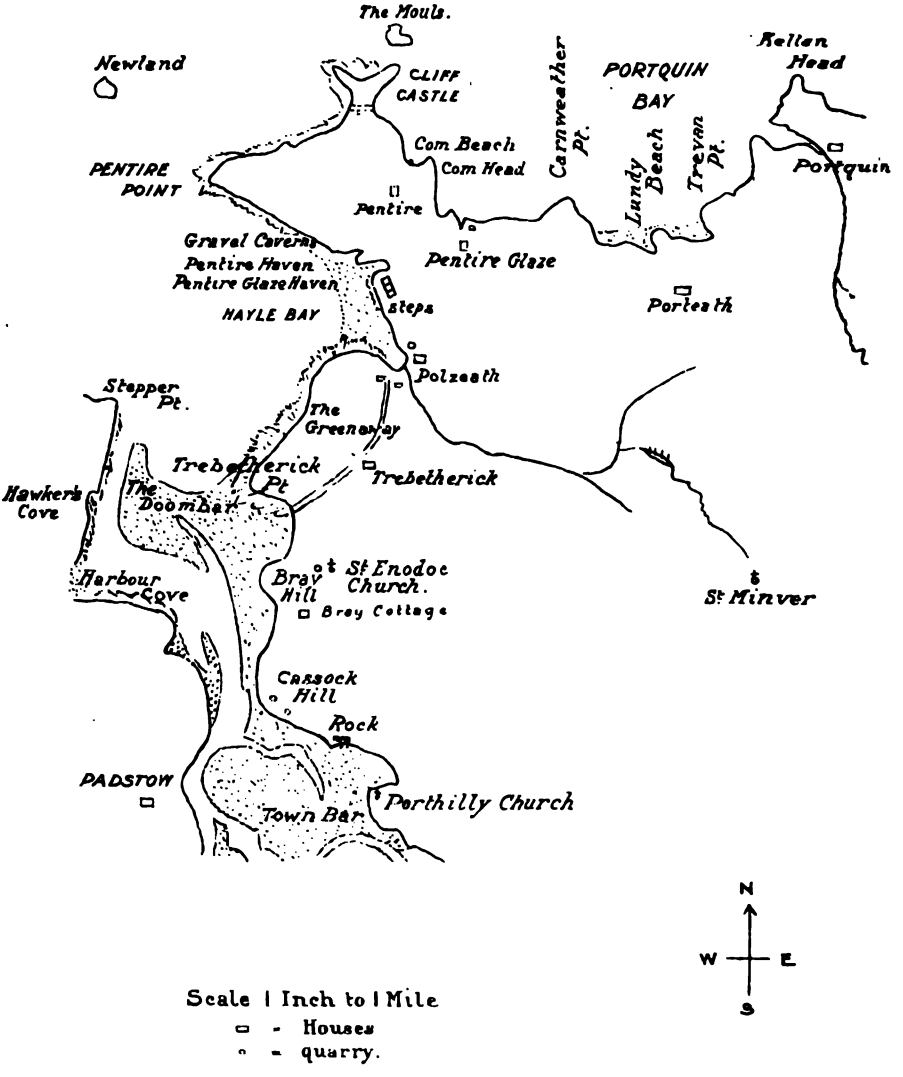
The second slide recalls 697*c* (block in foreshore of Pentire Haven). There are traces of lath-shaped felspars, now largely replaced by green alteration products, and apparently others of a semi-porphyritic nature. Possibly related to 690*a* and 690*b*.

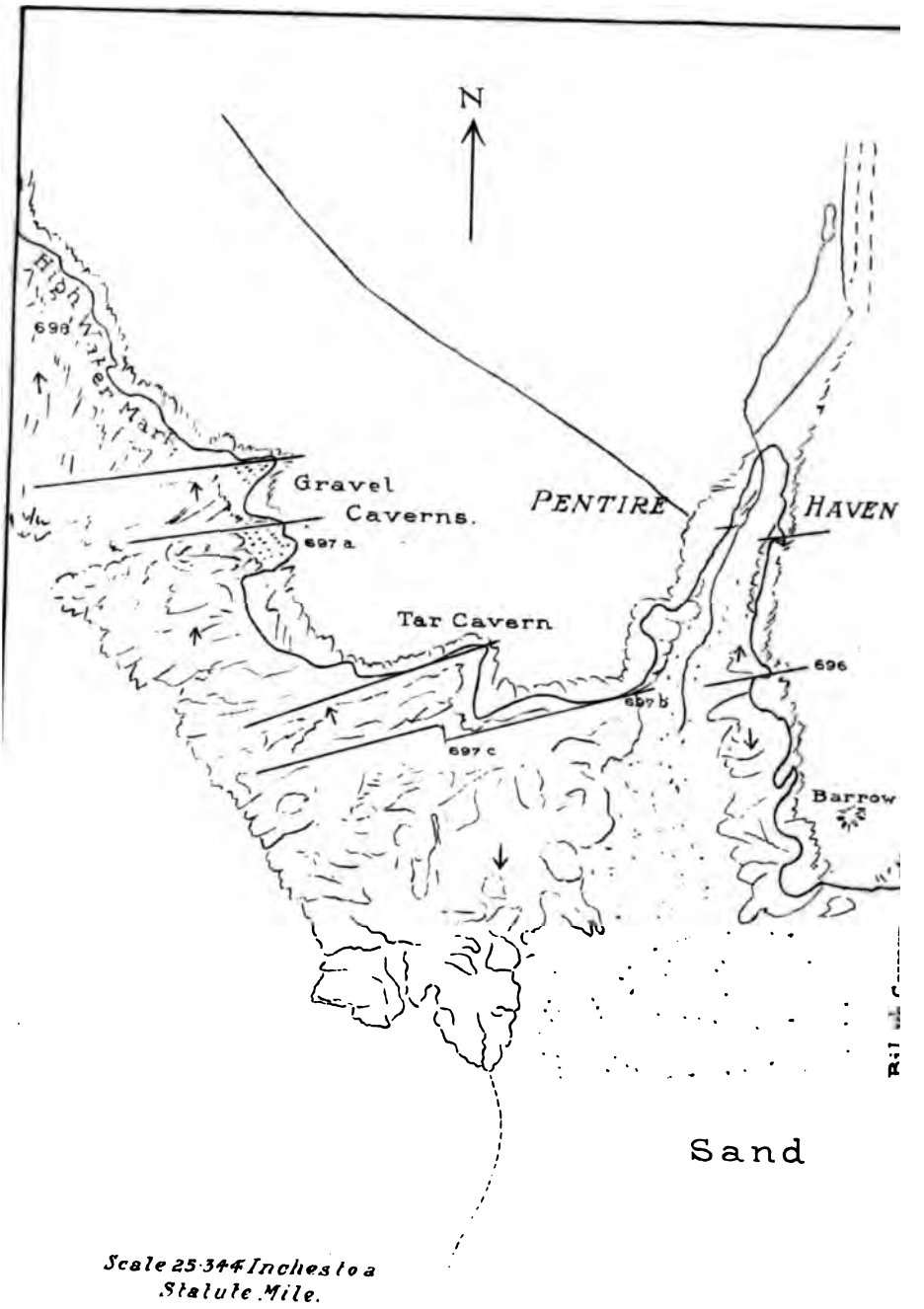
694. NORTH END OF GREENAWAY BEACH.

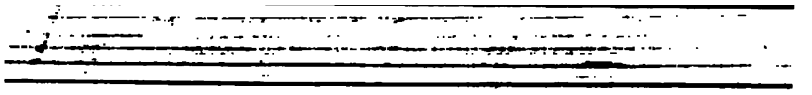
A greenish-grey rock, in which small subangular fragments or inclusions appear. It is an igneous rock, containing a few porphyritic crystals of quartz and orthoclase. The ground-mass is cryptocrystalline with minute lath-shaped felspars, arranged by flow, and somewhat indefinitely outlined (trachytic structure). Minute films of chlorite are developed in this ground-mass. Pyrites is an accessory mineral. The fragments are partly of slate, partly due to flow brecciation. The rock is allied to the dacites.

695. POLZEATH QUARRY.

A thick slice of an altered rock allied to others in the neighbourhood, *e.g.* 690*a*. Porphyritic felspars are present,


The Mouls.
Newland
CLIFF CASTLE
PORTQUIN BAY
Kellan Head
Com Beach
Com Head
Carnweather Pt.
Lundy Beach
Treyan Pt.
Portquin
PENTIRE POINT
Pentire
Pentire Glaze
Gravel Cavern
Pentire Haven
Pentire Glaze Haven
HAYLE BAY
Steps
Porteath
Polzeath
Stepper Pt.
The Greenaway
Trebetherick Pt
Trebetherick
Hawker's Cove
The Doom Bar
Harbour Cove
Bray Hill
St Enodoc Church.
Bray Cottage
St Minver
Cassock Hill
Rock
PADSTOW
Town Bar
Porthilly Church
N
W
E
S
Scale 1 Inch to 1 Mile
□ - Houses
○ - quarry.


N
High Water Mark
698
Gravel
Caverns.
697 a
PENTIRE
HAVEN
Tar Cavern
696
697 b
697 c
Barrow
Sand
Scale 25·344 Inches to a
Statute Mile.



though scarce, some of which may be orthoclase. Lath-shaped felspars, without orientation, are the principal constituent, but the slide contains abundant chlorite and traces of an inert brownish mineral which probably represent original augite or hornblende. Apatite and the alteration products of ilmenite are common accessory minerals. The rock is of intermediate composition.

696. PENTIRE HAVEN, EAST DYKE.

A rock consisting of numbers of lath-shaped felspars and of a brownish, inert, greatly altered mineral which may have been augite. Apatite, pyrites, and alteration products (leucoxene) of ilmenite are the accessory minerals. The rock resembles 691, of Cassock Hill Quarry.

697 { *a.* INCLUDED ROCK IN GRAVEL CAVERN BRECCIA.
b. PEBBLE IN SLATE, PENTIRE HAVEN.
c. BLOCK IN FORESHORE, PENTIRE HAVEN.

These may be grouped together, for although they exhibit differences, they seem to be slices of the same type of rock. In the second and third traces of lath-shaped felspars can still be discerned, set in a confused, rather opaque base, containing much opacite. The rocks are strikingly amygdaloidal, and recall strongly those of Pentire Head.

698. PEBBLE IN SLATE, PENTIRE POINT FORESHORE, NORTH OF GRAVEL CAVERNS (radiated margins).

A slaty rock, consisting of specks and minute flakes of chlorite, set in a colourless or pale flesh-coloured base, with low polarisation tints, appearing even isotropic in places Between crossed nicols the effect is that of a cryptocrystalline structure, common in these rocks, and apparently produced by the overlapping scales of a colourless chloritic mineral. This rock must be, I think, a kind of concretion in the slate.

699. Cliff east of Pentire Point.

An amygdaloidal rock. Microlites of oligoclase, and of a more basic variety, lie in an almost opaque ground-mass containing opacite and carbonates. The very numerous amygdaloids are composed of chlorite and carbonates. Phillips' analysis shows these rocks to be basaltic.

700. Slate entangled with 699.

A blue-black slate which has suffered from pressure, and is speckled with not very conspicuous white spots about ·015 inch across. The ground-mass contains much chlorite; white mica is absent; between crossed nicols the field presents a faintly speckled appearance. The spots are rounded to rectangular, occasionally prismatic in shape, colourless, and with many minute inclusions. They are clearly a product of contact metamorphism, and may be felspar.

701. Pentire Glaze Quarry.

Two thin sections have been prepared; both are of greatly altered rocks. As far as can be gathered, the first consists of rather stumpy, unorientated felspars, some sufficiently large to give the rock a semi-porphyritic character, and a ferromagnesian mineral. The latter forms small brownish and rather fibrous flakes (averaging about ·0075 inch in length), which are common throughout the slice, and, I believe, represent biotite. Small apatite needles are exceedingly common.

The second slice is of an amygdaloidal and much more finely grained rock. No certain remnants of felspar are left, but an acicular greenish mineral (now altered to chlorite, and plentifully sprinkled with opaque specks) apparently represents a ferromagnesian constituent resembling hornblende more than biotite. Apatite is absent. The rocks are of intermediate composition, recalling certain lamprophyres in some particulars. Compare 690*b*.

702. Lundy Beach, West Side, some 12 feet from nearest visible Igneous Rock.

A greenish-white slate, with obscure whiter spots in contact with a part more hornstone-like in appearance with rust-red spots. The latter fade into the whiter variety in about ·1 inch. The slate contains much chlorite without the development of white mica, and exhibits a finely speckled appearance between crossed nicols. The obscure spots are flocculent aggregates of a greenish granular mineral, with strong absorption. Each polarises as an individual, but cleavage and crystal form are absent. The rust-red spots (apparently a ferruginous variety) are opaque, but do not differ sensibly—except in colour—from those first described.

703. Lundy Beach from Same Position as 702.

A pale yellow or grey altered slate. The slate itself has the same microscopic structure as 702. A greenish mineral composes the spots. It is feebly pleochroic and inert, with the two nicols. It somewhat resembles a mineral of the ottrelite group, badly formed.

704. Lundy Beach.

Analysis—Na_2O. 9·35, K_2O. ·39.

The base of the rock is colourless and translucent, containing specks of an opaque mineral, yellowish white by incident light, possibly hematite, and minute flakes of a pale green chlorite. The latter also are aggregated together to produce short prismatic crystals (·035 inch × ·011 inch is roughly the average size), which are scattered over the greater part of the slide, and which usually form a mere framework, enclosing part of the base of the rock. Cross-sections of the prisms are rounded, subangular, or rarely hexagonal. Between crossed nicols the rock exhibits a finely speckled cryptocrystalline structure.

705. LUNDY BEACH. IGNEOUS ROCK.

Unfortunately greatly altered. It is, I believe, closely allied to 691, the Cassock Hill Quarry rock.

SUMMARY.

The following appear to be identical: the dykes at Porthilly Cove to the east of Rock (not included in the paper), Rock Quarry, the rocks of Cassock Hill Quarry, and possibly Lundy Hole and Beach. With these the Pentire Haven dyke, 696, shows affinities. They are fairly coarsely crystalline, and not amygdaloidal, excepting probably some specimens of 696. With the caution necessary, owing to their decomposed state, these rocks may be called doleritic camptonites.

The finer-grained variety of Rock Quarry, and the rocks of Bray Cottage and Pentire Glaze, are more characteristically lamprophyric. The very amygdaloidal basaltic rocks are typically represented by 699, and belong to a different category.

In concluding these notes I wish to express my sincere thanks to Mr. Howard Fox for his kindness in showing me over the district and for aiding me with specimens and information derived from his many visits to the coast.

LEADBEARING LODES OF CORNWALL.

PLATE I.

UPFIELD GREEN,

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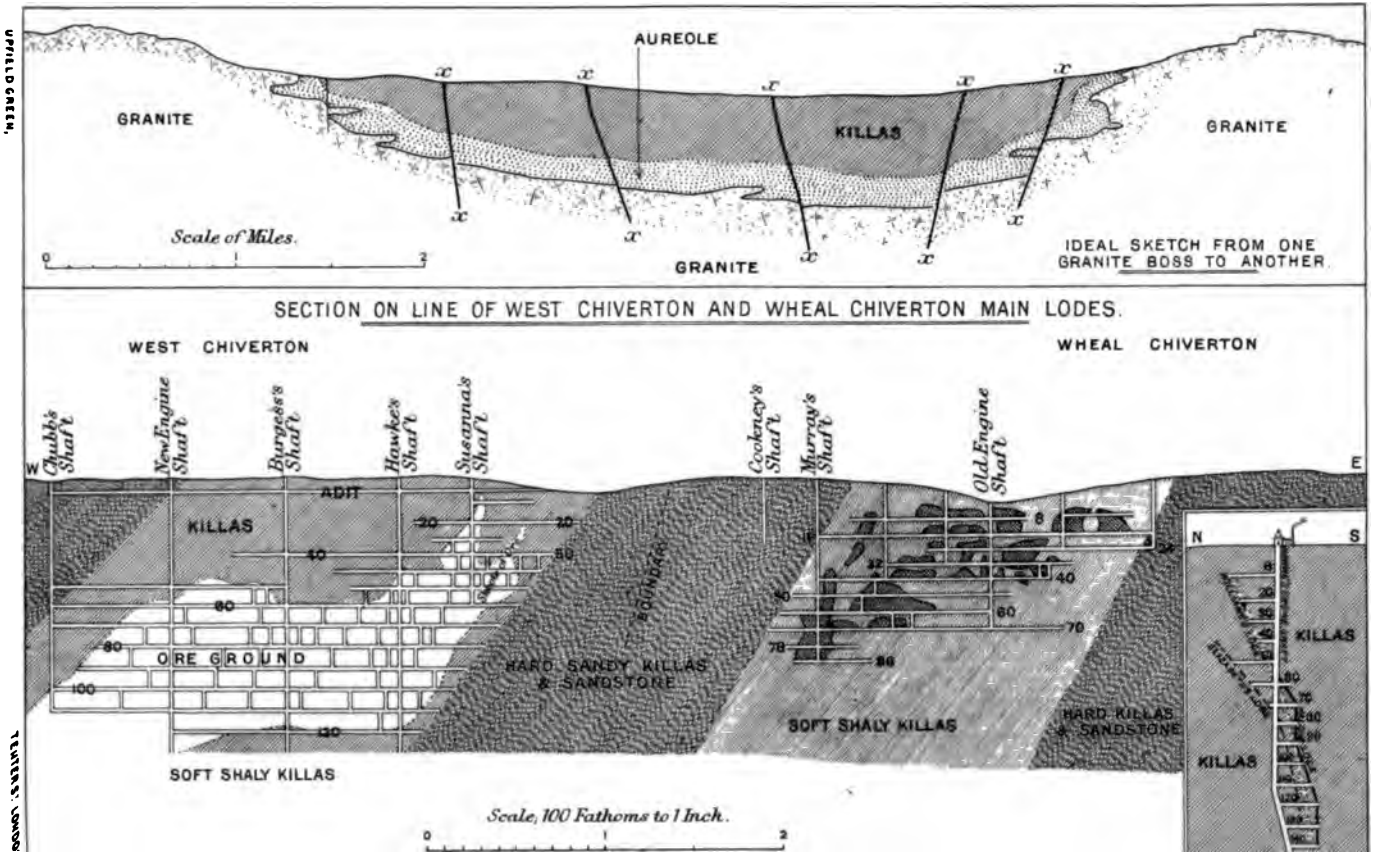
AUREOLE
GRANITE
KILLAS
GRANITE
Scale of Miles.
0 1 2
GRANITE
IDEAL SKETCH FROM ONE GRANITE BOSS TO ANOTHER.
SECTION ON LINE OF WEST CHIVERTON AND WHEAL CHIVERTON MAIN LODES.
WEST CHIVERTON
WHEAL CHIVERTON
W
E
Chubb's Shaft
New Engine Shaft
Burgess's Shaft
Hawke's Shaft
Susanna's Shaft
Cookney's Shaft
Murray's Shaft
Old Engine Shaft
ADIT
KILLAS
ORE GROUND
HARD SANDY KILLAS & SANDSTONE
BOUNDARY
SOFT SHALY KILLAS
SOFT SHALY KILLAS
HARD KILLAS & SANDSTONE
N
S
KILLAS
KILLAS
Scale, 100 Fathoms to 1 Inch.
0 1 2

NOTES ON THE PRINCIPAL LEAD-BEARING LODES OF THE WEST OF ENGLAND.

By J. H. Collins, F.G.S.

Historical Notes.—The early history of lead (and silver) mining in the West of England is very meagre and fragmentary. It is well known that the Romans worked the Mendips extensively for lead in the early centuries of the Christian era, and that they extracted silver from some of the lead so obtained. The extent of their workings in this region must indeed have been considerable, and it lasted for centuries.[1] Farther to the west the lead ores are in general much richer in silver than in the Mendips, and they have often been worked for their silver contents alone.[2]

At Combe Martin, on the north coast of Devon, a few miles from Ilfracombe, several veins containing argentiferous lead ore have been known for many centuries, and are said to have been discovered by tinners while searching for or working

[1] See Hunt's *British Mining*, pp. 31, 36, 131, etc.

[2] True silver ores, yielding many thousands of ounces to the ton, have been found from time to time in many of the mines of Devon and Cornwall.

alluvial tin. These veins mostly course in a S.E. to N.W. direction. The earliest accounts of mining in this district, as also in West Devon (Beeralston), refer to silver, and date from the year 1293, when Wm. de Wymyndham, King Edward's factotum, accounted to the Treasury for 270 lbs. weight of refined silver; in 1294 he accounted for 521½ lbs., and in 1295 for 704 lbs. This silver was no doubt obtained by cupellation from argentiferous lead ores. It was mainly produced by the labours of "foreign" miners, of whom more than three hundred were imported from Derbyshire and twenty-five from Wales.[1]

It is not known how long these mines continued to be worked on behalf of the king, but "in 1360 a writ was issued authorizing certain persons to take up as many miners and workmen as should be necessary to work in the king's mines in Devon, allowing them reasonable wages according to the custom of the country; to arrest and imprison such as should resist till they should give security to serve the king in the said mines; and to buy and provide timber at a competent price." The work does not seem to have progressed very briskly, however, for Henry, Bishop of Winchester, Cardinal of England, and one of the executors of John, Duke of Bedford, who had a grant from the king of the gold and silver mines of Devon and Cornwall, rendered 26 lbs. and 2 ozs. of pure silver as

[1] See Holinshed, quoted by Henwood, *Trans. R. G. S. C.*, viii. p. 109.

the fifteenth part of the pure silver raised in those counties from December 15th of the twenty-first to August 16th of the twenty-third year of the same king's reign.[1] Nothing more is known of the mines for more than a century; but in the year 1485 there are said to have been 1,000 men employed here and at the mines of Beerferris, on the Cornish border.

In 1587 a new mine was discovered at Combe Martin by Adrian Gilbert and John Popler, who sold the half of it to Sir Bevis Bulmer. This "Faye's Mine" was soon sunk to a depth of 32 fathoms, and an ore-shoot of the same length was worked, which at first yielded profits equal to £20,000 per annum, but later only £1,000 per annum. The "last cake" of silver from the smelting works in this mine was sent up to London, and there, having been made into a cup and cover by Mr. Medley, a goldsmith in Foster Lane, was presented to the City Corporation "to remain from yeare to yeare, yearly for ever unto the Honourable the Lord Maior of London." The cup had Mr. Bulmer's picture upon it, with the following verses:—

"When Waterworks at Broken Wharf
At first erected were
And Bevis Bulmer, by his art
The water 'gan to rear,
Dispersed I, in earth did lie
From all beginnings old

[1] *British Mining*, p. 131.

In place called Combe, where Martyn longe
Had had me in his moulde
I did no service on the earth
For no man sett me free
Till Bulmer, by his arte and skill
Did frame me this to be."[1]

Many particulars as to the history of the Combe Martin mines are recorded by Mr. Bushell, a pupil of Sir Francis Bacon and a celebrated mineralogist. He strongly recommended the reworking of the mines to the Long Parliament in 1659, but the Restoration followed, and the next Parliament found other matters to attend to.

In 1784–5 the mines were certainly at work on a small scale, for they produced 6,500 ozs. of silver in the course of a year. In 1813 they were again opened and worked for four years, but they yielded only 208 tons of silver-lead ore in that time. They were again reopened in 1837, but did not continue long at work.

The West Devon Mines.—Near Okehampton and Tavistock many lead mines have been worked from time to time, but none of them have been really important. To the north of Dartmoor, near Okehampton, the mines known as Holestock and Castle have been worked a little at various times, and the same may be said of the mines grouped as the Lydford Consols, some miles farther to the west.

In the neighbourhood of Tavistock, Wheal

[1] *The Discoverie and Historie of the Gold Mines in Scotland*, by Stephen Atkinson.

Betsy, known also as North Wheal Friendship, has been perhaps the most important lead mine. This is situated in the parish of Mary Tavy, about four miles north of Tavistock. The main lode is the same vein as the eastern cross-course of Wheal Friendship, which lies farther to the south and nearer to the granite. This vein varies in width from 2 to 3 feet, and is mainly composed of quartz where it crosses the great copper lode, but in Wheal Betsy it is much smaller, generally from 6 inches to 3 feet, and here it is composed of quartz, slaty clay, earthy brown iron ore, carbonate of iron and blende, with leaders and pockets of galena. Wheal Betsy is a very ancient mine, and it has been worked at several distinct times. After a long period of idleness it was reopened in 1806, and in 1821 it was returning 400 tons of lead per annum, which was, for the West of England, rather unusually poor in silver—about 12 ounces to the ton. Somewhat later the mine returned 45 tons per month, which barely paid expenses. In 1843 it was 110 fathoms deep, and both water- and steam-power were employed in draining it. The mine was finally closed in 1877.

In the Tamar Valley, in the parishes of Beeralston and Beerferris, several rich and productive mines have been worked for argentiferous lead ores in past times. The most important deposits were found in a N. to S. vein extending from the River Tamar at Calstock to a bend of the same river three miles to the southward. At that point it

disappears under the waters of the Tamar, whose lower course is the same as that of the vein to and beyond Saltash. Northward from Calstock the vein has been traced as a sparry cross-course, but it no longer contains more than traces of galena.

A second parallel lode exists about three-quarters of a mile to the westward, and this also has yielded lead ore at intervals over a course of more than three miles, crossing the bends of the Tamar no less than three times.

The lead ore of these mines was exceptionally rich in silver, often running up to 100 and even 170 ounces to the ton.[1]

The Tamar mines were reopened soon after 1832, and in 1836 they were drained to the 75-fathom level. Later they were drained and worked to the 145-fathom level. Three steam-engines and several water-wheels were employed.[2] In 1841 the mines produced £14,646 worth of ore at a cost of £12,067.[3]

South Tamar Consols was also a successful mine until the year 1856, but in August of that year the

[1] From the lead mines of Beeralston a large quantity of silver has been extracted. The produce of one vein averaged about 70 ounces to the ton. Another vein produced 170 ounces (*Rees' Encyclopædia*, article "Silver").

Lead from shallow parts of the Tamar mines contained about 145 ounces to the ton, but from the deep levels from 35 to 40 ounces (P. N. Johnson; see Henwood, *Trans. R. G S. C.*, viii. p. 110).

[2] "In the Tamar lead mine, Beerferris, a 20 horse-power steam-engine was erected at the 140-fathom level to pump water and raise ore. The smoke was conveyed along the old workings" (see Pepper, quoted by Henwood, *Trans. R. G. S. C.*, viii. p. 609).

[3] The total outlay to that time (of that working) had been £18,000, while £22,500 had been given in dividends.

waters of the Tamar broke in, and the mine was drowned out.[1] Other mines in the neighbourhood were known as East Tamar Consols, Tamar Valley, and South Ward. This latter mine was 20 fathoms deep in the year 1870, and employed 12 people.[2]

South Devon Mines.—In the Upper Teign Valley, Frank Mills, Wheal Exmouth, and Wheal Adams were mainly on one lode, which is traceable for some miles along the valley. At Frank Mills the lode was in general from 2 to 4 feet wide, and contained the usual fragmentary filling with occasional leaders of solid galena and veinlets of blende and pyrites. A good deal of barytes was also found in the lode in places, sometimes in very beautiful crystals.[3] Frank Mills was worked below the 175-fathom level; Wheal Exmouth and Wheal Adams were not nearly so deep.[4] Other lead mines in South Devon have been worked near Ivybridge,

[1] The dividends distributed up to 1856 amounted to £70,620; the calls had been £43,200.

[2] The last workings of the Tamar mines since the year 1848, when Mr. Hunt's "Mineral Statistics" began to appear, gave results as under :—

		Lead ore (tons).	Silver (computed oz.).
Tamar Mines . .	1848–1863 ...	13,291 ...	600,000
Tamar Consols . .	1849–1860 ...	7,116 ...	320,000
East Tamar Consols .	1848–1861 ...	2,338 ...	46,000

[3] The writer has crystals half an inch long or more, which he obtained thirty years ago from some of the old levels, which had evidently been formed after those levels had been driven.

[4]

Frank Mills . . .	1857–1880	produced 14,303 tons of ore.
Wheal Adams . . .	1848–1852	„ 1,133 „
Wheal Exmouth . . .	1851–1853	„ 1,591 „
Wheal Adams and Exmouth	1854–1874	„ 9,983 „

It is not known how much ore was produced before the year 1848, but it was probably much more than is here stated. The silver seems to have varied from 10 up to 20 ounces per ton of ore.

such as Boringdon Park and Boringdon Consols, but only to a very small extent.

East Cornwall.—Three miles west of the Tamar is a lead-bearing cross-course which traverses Hingston Downs from north to south. This vein, when worked at Wheal Vincent and other mines to the south of the downs, was found to be very rich in silver, but none of them produced any large quantities of ore. A mile or so farther west is the Holmbush vein, which passes southwards through the town of Callington and the Colquite Estate, and northwards through Holmbush mines. Here the lead vein was worked below the 150-fathom level, but the records of production are very imperfect.[1]

The Mary Ann-Trelawny lode, which crosses the county from north to south about four miles farther to the west, has been worked upon for a length of three miles, and was found to be very rich in Wheal Mary Ann and Wheal Trelawny for a length of a mile or more.

The vein where worked in these mines varied in direction from 8° east of north to 5° west of north, having an eastern dip of from 60° to 80° from the horizontal. The width varied from 2 feet to 6 feet, with an average of about 4 feet. The slaty rocks

[1] The following figures may, however, be relied upon for the periods named :—

Holmbush, 1848-1857, produced 585 tons of lead ore.
Callington, 1848-1854 „ 3,127 „ „

The east and west lodes in these mines have yielded large quantities of copper and arsenic, and at Redmore of tin.

traversed by this lode have mostly a gentle inclination to the southward, but occasionally to the northward; they are greenish, brown, drab, or dun-coloured near the surface, homogeneous, and of silky appearance; at moderate depths they are usually deep greyish or blackish blue. They are occasionally interstratified with felspathic and hornblendic beds, some of which seem to be altered ash beds.

Like all the other lead veins of the West of England, it is a true fissure lode, containing much crystallised quartz, while the walls are often lined with some inches of "capel," or "cab," consisting mainly of chalcedonic quartz. The interior of the vein, besides quartz, contains calcite, chalybite, galena, fluor, barytes, and many other minerals. Horses, vughs,[1] and combed structure are all frequent. Drusy deposits of pyrites, galena, and other minerals were frequently seen on the upper surfaces of the larger crystals and fragments.

The phenomena of this lode have been well described by several writers. Mr. Giles notes that in the shallow levels much carbonate and phosphate of lead were found, particularly at Trelawny. At this mine, too, down to the 40, many fine crystals of barytes were met with, but below that level only pseudomorphs.[2]

Dr. Le Neve Foster gave three interesting sections of the lode as seen in the 250-fathom level

[1] Some of the vughs met with were many fathoms long, and in height sufficient to extend from one level to another, *i.e.* 10 fathoms or more.

[2] Giles, *Trans. R. G. S. C.*, vii. p. 198.

at Wheal Mary Ann in the year 1874, shortly before the mine stopped, from which a part of the history of this remarkable ore-deposit may be plainly inferred. He gives the order of deposition of the various minerals as seen in these sections, and adds, "There have, therefore, been at least two periods of formation of fluorspar; the lead ore was deposited at an intermediate period, and the last minerals have been quartz, chalybite and calcspar." The galena, which always contained from 30 to 90 ounces of silver to the ton of dressed ore, did not occur in a continuous mass or leader for long distances, forming well-defined "shoots" or "courses"; rather, it consisted of a series of little lenticular bodies connected by threads of mineral. Yet the lode proved productive at Wheal Trelawny for nearly 500 fathoms in length, and at Wheal Mary Ann for about 300 fathoms. It was also worked profitably in the Trehane sett.

This lode was very vigorously worked for about a third of a century, beginning in 1843.[1] In 1864 a depth of 200 fathoms below adit had been reached, and in 1870 over 300 fathoms. At one time about 1,000 people were employed, there were four pumping-engines, three engines employed in raising and crushing ore, besides several water-wheels. The ores produced realised close upon

[1] Trelawny began work in 1844, and stopped in 1871. Mary Ann began in 1846, and stopped in 1876. Together they yielded ores to the value of £919,769. Trehane was worked from 1843 to 1857, and yielded 4,219 tons of dressed ore from 1848 to 1857. Wheal Hony in 1883-4 yielded 88 tons, value £1,131.

one million sterling, the royalties amounted to near £100,000, and the profits divided were about £130,000, the subscribed capital having been a few thousands only. A remarkable feature at this mine is the broad belt of "slidy ground" which was met with in following the lode to the south. A similar belt was found in the Herodsfoot Mine, to be referred to hereafter.

The great lode just described, in going northward, passes through the Ludcott and Wheal Wrey Mines, where it has been worked as the Ludcott west lode to a certain extent. Parallel to this, and about 60 fathoms to the eastward, is the principal Ludcott and Wheal Wrey lode. This traverses a "country" of the same character as that existing at Wheal Mary Ann and Wheal Trelawny. The lode, too, has many resemblances to the Trelawny lode, and has almost the same course and underlie. It was notable, however, in Wheal Wrey on account of the occurrence of very large and perfect crystals of barytes and fluor, and in some parts of Wheal Ludcott because of certain remarkable deposits of rich silver minerals, native silver, argentite, pyrargyrite, proustite, stephanite, etc., in very considerable quantities.

Wheal Wrey Consols was an old mine restarted in 1853, and worked independently until the year 1863, when it was united with Wheal Ludcott, which had been restarted in 1856. The united mines worked on till 1866.

In Ludcott the lode was worked to a depth of

nearly 90 fathoms. About 1861 a considerable amount of rich silver ore was found in the back of the 70-fathom level, principally at the intersection of the lode by a run of "slidy ground" running E. to W., and locally termed a cross-course. The lode itself was rarely very rich, but the silver-bearing portion of the "cross-course" was in places 2 to 3 feet wide, largely interspersed with argentite, "and worth probably, at points, more than £1,000 per fathom. At the richest points the sulphide is the principal ore, but a considerable quantity of native capillary silver is also met with, and also some fine specimens of ruby silver . . . almost invariably accompanied by a considerable proportion of white iron (chalybite), with which it seems to have some distinct relationship."[1]

The silver ore "in sight" above the 74 was valued by Captain Charles Thomas in 1862 at from £6,000 to £8,000. One ton of selected ore was sold for £694, and 123 tons of variable grade realised over £10,000. Only partial returns of the lead ores sold are available, but the following are correct as far as they go: Wheal Wrey Consols, 1853–62, sold 5,435 tons of ore; Ludcott, 1856–62, sold 3,108 tons of ore; Ludcott and Wrey, 1863–66, sold 1,870 tons.

Herodsfoot is situated about $3\frac{1}{2}$ miles to the south-west of Liskeard. The lode courses through killas of the same character as that of Trelawny, and is very nearly N. to S.; it underlies to the

[1] Salmon, *Mining and Smelting Magazine*, ii. 83, 1863.

west about 1 in 6 (70° from the horizontal), and varies in width from a mere joint up to 3 or 4 feet wide. The vein stone was mostly quartz, often of a saccharine texture, and with this there was a great deal of iron pyrites and blende, with occasionally considerable bunches of antimonial sulphide of copper (tetrahedrite).[1] The ore "made shallow" in the valley, where the workings date from the end of the eighteenth century, if not earlier. After a period of stoppage they were re-opened about 1844, when the mine at the old engine shaft was found to be 50 fathoms deep. The ore-ground was not very rich, but there was a great deal of it, and it was followed down to a depth of about 150 fathoms, some of the levels being extended for a distance of 140 fathoms to the north of the shaft, while southward they were driven up to a belt of "slidy ground" for an equal distance, where the lode was found to be broken up and valueless.

According to Mr. Giles, this "slidy ground" was of "intrusive origin," having an imperfect laminated structure. It passed through the lode and heaved it.

To the south of this belt of broken ground, as also south of a second "run" subsequently met with near the new shaft, the ore was found to be much richer in silver than it had been to the north.

In the year 1855 the mine was very poor, and water had been allowed to rise to the 137-fathom level. A change of management was then made;

[1] Giles, *Trans.* vii. p. 198.

Çaptain Trevillion took charge, and some new capital was raised. A new shaft was sunk[1] 140 fathoms deep, and levels communicated with the old levels to the north of the "slidy ground," the 82, 106, 117, and 127 being also driven south of the new shaft by the year 1861, so opening up large quantities of ore-ground—ordinarily worth 9 or 10 cwts., but occasionally 2 to 3 tons of lead ore to the fathom. In some parts this lode was highly brecciated and exceptionally rich in silver.

The effect of the "slidy ground" from a mining point of view was thus described by Mr. H. C. Salmon in the year 1862: "When this ground was first met with in the levels the prospects of the mine were very gloomy; the old bunch of ore was evidently gone in depth, and in both ends the lode seemed to be shattered beyond recovery . . . the whole strata seems to be broken up by a succession of disturbances of a nature between cross-courses and slides. . . . This broken ground generally extends for a considerable width, shattering and, indeed, obliterating the lodes . . . although now and then detached pieces, sometimes rich, are found in it. Its width in Herodsfoot is about 60 fathoms at surface, and 30 fathoms at a depth of 150 fathoms (the course is nearly E. to W.); it also shortens (narrows) in depth, as in my experience I have found to be almost invariably the case in

[1] The method of sinking the lower portion of this shaft was peculiar. The ground was first worked away, and then the shaft was built and stowed in the "gunnies."

broken channels of ground of this kind. The mine was nearly abandoned at this period, but fortunately the hopeful counsels of Captain Trevillion prevailed . . . the broken ground has been passed through, and what is to all intents and purposes a new mine has been opened out south."[1]

The mine was worked cheaply and at a moderate rate. For some time the produce was 40 tons of lead ore per month and the profit £5,000 per annum.[2]

North Cornwall.—Lead-bearing veins coursing N. to S., or nearly so, are found at small intervals along the whole of the north coast from Tintagel to St. Agnes, but few of them have been at all extensively explored or profitably worked. The best-known veins east of the Padstow River are those worked in Old Treburgett Mine in St. Teath, Wheal Boys in Endellion, and Pentire Glaze in St. Minver. In all of these mines the lead was associated with antimony, and often with copper also. The workings are very ancient, and very little is known of their extent or of the commercial results of the mining operations. Old Treburgett was remarkable for its occasional ore-shoots of rich antimonial silver, though the lead ore itself was

[1] *Mining and Smelting Magazine*, ii. 213.

[2] From 1848 to September, 1862, there were sold 9,648 tons of ore for £146,992. In 1864 the mine had reached a depth of 150, and in 1870 165 fathoms, and then employed 170 people. It continued to work until the year 1884, but only on a small scale. The same lode has been worked to a small extent, northwards in North Herodsfoot and southwards in South Herodsfoot, for a total length of over a mile.

usually poor in silver; Wheal Boys was notable for the purity of its Jamesonite and other antimonial sulphides, and for the first discovery of the beautiful triple sulphide (of lead, copper, and antimony) known as Bournonite, while Pentire Glaze yielded many especially beautiful crystal groups of carbonate of lead (cerussite). All the lodes in this neighbourhood were narrow, rarely exceeding 24 inches wide, and often much less, except where occasional rich pockets were found.[1]

Central and West Cornwall.—The region from Padstow to Newquay, and extending thence southward to Truro and westward to Perranzabuloe, contains many N. to S. lead veins, besides some whose course varies in direction from a few degrees E. of N. to almost E. and W. Scores of these have only been opened by trial pits or shallow adits, but Old Shepherd's, Garras, and Ventongimps were notable mines in the eighteenth century.[2]

In Garras Mine (Guarnek), which is about 3 miles to the north of Truro, the direction of the lode is nearly N. to S., its width varies from 2 to 6 feet, and it is heaved twice by slides. The ore richest in silver was found between these slides

[1] Wheal Boys has yielded 100 tons in a year of regulus of antimony, 8 in 20 of pure antimony. It does not now produce half that quantity (Carne, *Trans. R. G. S. C.*, ii. p. 113 [1818–22]). Pentire Glaze from 1850 to 1856 (its last working) yielded 1,324 tons of lead ore, averaging about 40 ounces of silver to the ton. Old Treburgett from 1871 to 1879 (its last working) yielded 2,177 tons of lead ore, averaging only a few ounces of silver to the ton.

[2] In Old Shepherd's the lodes run about 20° N. of E. This mine was worked by Sir Christopher Hawkins to a considerable depth. A plan to reopen it in 1881 failed for lack of capital.

at about 70 fathoms from surface. Garras was worked as far back as the year 1720, when some of its lead contained 100 ounces of silver to the ton. In 1814, after a long period of inaction, the mine was again set to work, and so continued for about two years. During this period it produced 850 tons of silver-lead ore, containing 65% lead. The ore was smelted and the silver extracted on the spot; it amounted to 70 ounces to the ton of lead.[1]

Wheal Rose is a few hundred fathoms to the south of the Shepherd's mine and two miles north of Guarnek. The lodes, which run nearly E. to W., were discovered by Sir Christopher Hawkins, and worked with some success by Messrs. John Taylor and Sons in the early part of the nineteenth century.[2]

East Wheal Rose was a great mine towards the close of the second quarter of the nineteenth century and for some time after. In this mine there are junctions of the Shepherd's and Wheal Rose lodes. In particular there are two lodes meeting nearly at right angles, which were almost equally productive for many fathoms on either side of the points of contact.[3] Northward from these junctions the N. to S. lode continued to be productive

[1] Carne, *Trans. R. G. S. C.*, i. p. 120.

[2] "The veins which have been lately discovered in the parish of Newlyn by Sir Christopher Hawkins in draining a marsh. They are about 2 feet wide and run nearly E. to W. (mag.). . . . Besides lead and a little quartz, they consist entirely of clay."—Carne, *Trans. R. G. S. C.*, ii. p. 114, 1822.

[3] "A case, so far as I know, without a parallel in Cornwall."—Henwood, *Trans. R. G. S. C.*, v. p. 268.

for a long distance; but southward, although it has been traced along the River Allen as far as Treworgan Mill and perhaps farther, it soon ceased to be productive. A great part of the main lode consisted of "sandy" or "running" ground, so that it was often necessary to keep the "ends" closely boarded up and to allow the loose ore to flow out into a bucket through a narrow opening.[1] The average yield of the ground for a long time was about 10 cwt. of ore to the fathom.

This was the most important lead mine in the West of England when the "Mineral Statistics" were begun by Mr. Robert Hunt in the year 1843, in which year the mine yielded 5,333 tons of dressed ore.[2]

From 1834 down to 1855, when the mine changed hands, the total calls had only amounted to £6,400; the total costs during the same period had been £471,850, and the dues paid £53,178. The ores sold had realised more than three-quarters of a million sterling, and this, when added to the proceeds of the sale of the mine, enabled the managers to distribute £274,500 as dividends among the fortunate shareholders.[3] The new

[1] "At the exceedingly productive mine of East Huel Rose, in Cornwall, not only is the 'killas' very soft, but the lode itself, including its saccharoid quartz or 'sugary spar,' is in so disintegrated a condition that a blow with a pick will often cause it to run down like a quantity of sand and mud."—Smyth, *Mem. Geol. Survey*, ii. p. 655, 1848.

[2] In the previous year a "cloudburst" had suddenly filled the valley with a torrent of water, which, making its way down a shaft, drowned forty men.

[3] R. Michell, *Trans. R. G. S. C.*, viii. p. 454, *note.*

company continued to work the shallower levels of the mine down to the year 1861, but incurred in all losses estimated at £30,000, including the price paid for the property.[1]

After twenty years' suspension of operations the mine was reopened in 1881 by a limited company having a *nominal* capital of £100,000. Two large pumping-engines were erected (90″ and 100″ cylinders respectively), under the direction of Mr. Loam, of Moditonham, and a good deal of the water was got out. However, the company went into liquidation before any important underground explorations had been effected.[2]

Other once important lodes in this region are at

[1] The sales of lead ore during the last five years of working were as under:—

1857	1,199 tons.
1858	726 „
1859	728 „
1860	607 „
1861	147 „
	3,407 „

Besides this a little blende was sold.

[2] On the occasion of starting the first great pumping-engine in 1882 Dr. Vigors said that he had seen the lode in the bottom of the mine (150 fathoms) "as wide as his two arms could stretch across . . . there were large stones of lead, and other portions of the lode would 'run like a river,' half lead." The accuracy of this statement was never brought to the test, for the bottom was not actually drained.

The ore-sales during this last working were as under:—

1882:	Lead ore,	40 tons;	blende,	70 tons.
1883	„	155 „	„	161 „
1884	„	85 „	„	— „
1885	„	50 „	„	— „
1886	„	58 „	„	— „

This ore was obtained partly from the shallow levels and partly from the old waste-heaps.

Goonhavern, which lies to the south-west of Old Shepherd's, and Cargoll, which is a little to the west and was once worked as part of the East Wheal Rose sett. Cargoll has been worked to a depth of 185 fathoms in all, but in the last working, at any rate, there were no very satisfactory results.[1]

The lode once so largely and profitably worked in Wheal Chiverton (Old Chiverton, or Venton-gimps), and afterwards in West Chiverton, courses nearly N.E. and underlies to the S.E. At West Chiverton the principal lode (Williams's) bears 40° N. of E., and underlies to the S. of E. about 2 feet in a fathom; an important branch, known as Valpy's lode, detached itself from the hanging-wall at a depth of 50 fathoms and rejoined the main lode between the 90- and 100-fathom levels, thus enclosing a large "horse" which was nearly 100 fathoms long. Another lode (Elizabeth's), parallel to Valpy's in direction but having a greater underlie, formed a junction with Williams's on its footwall at about 80 fathoms' depth. All these lodes underlie to the southward, Williams's being in general the largest and most constant. In this lode the galena was found to be pretty generally disseminated throughout the veinstone; in Valpy's it was more often in solid and massive leaders, while in Elizabeth's it was often dispersed through a clayey

[1] Cargoll, from 1849 to 1873, produced 11,942 tons of lead ore, worth probably £180,000, besides at times considerable quantities of rich copper ore (from 1864 to 1871) and of blende (from 1864 to 1873). The value of these subsidiary products was not less than £20,000.

matrix and was, on the whole, richer in silver. Williams's lode was usually from 2 to 6 feet wide, the others only from 1 to 3 feet, except at the points of junction.

The "back" of Williams's lode was sparry to a depth of 40 fathoms from the surface, where the great ore-shoot was first seen in the bottom of the level as a small "pipe" of ore in the lode, which rapidly spread out until at the 90 it was 200 fathoms long. At this level the workings presented a very fine aspect. Stopes of 27 feet wide were being removed, the men standing upon the "deads." The back showed a series of veins of galena, blende, and quartz, each of which carried in places a rich leader of 12 to 16 inches in width. This great size and richness was thought to be due to the coming together of the three lodes. In several cases the "ends" were valued at £100 and even £150 per fathom for lead and silver. In many parts of the lode there were strong ribs of blende, which, at first of no value, were afterwards worked away (from 1873–1881) with great advantage.

There are no records of the earlier workings in the adjoining mine, Wheal Chiverton; but the old plans show that the mine was only sunk to a depth of 86 fathoms and that large stopes were worked away. It is said that lead ore to the value of over £100,000 was obtained, although there was a considerable loss.[1]

[1] Salmon, *Mining and Smelting Magazine*, v., 1864.

In both mines the productive parts of the lodes were in rather soft, shaly beds of a yellowish tint; the unproductive beds were dark greyish blue and of a sandy character, passing into a fine conglomerate. These beds dipped S.W., and the shoots did the same; this was plainly shown on the mining sections, and it seems likely that both shoots might have been profitably followed to far greater depths than were attained when the mines stopped[1] (see section, Plate II.).

Lead Lodes of South Cornwall.—The country between Porthleven and Helston at one time yielded considerable quantities of lead and silver. Wheal Pool, near the head of the Looe Pool, was at work towards the close of the sixteenth, and was again worked profitably about the middle of the eighteenth century. In 1790, after a period of idleness, it was reopened, when the ore was found to contain from 30 up to 60 ounces of silver per ton. At that time it had its own smelting works. Wheal Penrose was an important mine early in the sixteenth century.[2] Wheal Rose,

[1] The total sales of lead ore from West Chiverton from 1862 to 1886 amounted to 44,715 tons. The value is not given in all cases in the "Mineral Statistics," but we shall not be far wrong if we take it at an average of £14 per ton, in all £626,010. The mine also produced 22,406 tons of blende during that period, which sold for £67,217.

[2] An agreement for working Wheal Penrose, made between Mr. Thomas Penrose, then owner of the land surface, and Sir William Godolphin, then lessee of the Crown Minerals, bearing date 1625, is in the possession of Captain Rogers, of Penrose. It is said that there was a rich bunch of galena at this mine, which was followed up to the surface.

which was worked about the same time on a parallel lode, had a "fire-engine" working in 1746, and was then more than 50 fathoms deep.[1]

Other lead mines worked in the Helston district were known as Wheal Unity and Wheal Saturn. These lodes yielded large quantities of blende, carbonate of iron, and iron pyrites, and the old workings above adit, when reopened by Mr. John Hunt about 1870, were found to be beautifully coated with druses of pyromorphite.

Several lead lodes are known, and have been worked to a small extent in the neighbourhood of Falmouth, and across the harbour near Trefusis. Of these the most important is probably that which was worked many years ago as the Swanpool Mine. This mine, however, was perhaps more remarkable on account of the important electrical observations that were made there more than half a century ago by Mr. Robert Were Fox, and on account, too, of the early smelting experiences of Sir William Roberts-Austen, than for the richness and quantity of its ores.[2]

Some General Characters of the Lead Lodes.—In all these mines very similar lode phenomena have

[1] The Wheal Rose lode is supposed to be the same vein as that which a little farther to the north is known as Woolf's cross-course. This cuts through the lodes of Wheal Fortune, Wheal Metal, Wheal Vor, and Polladras, and then traverses the Godolphin Mine, where it yielded large quantities of rich copper ore (see Hancock, *Report M. A. of Corn. and Dev.*, 1870, p. 39).

[2] The Swanpool Mine, from 1854 to 1860, sold 6,022 tons of lead ore, which were said to contain 30,983 ounces of silver, but probably did contain several times as much of that metal.

been observed. The lode fissures are all of comparatively late origin as compared with those yielding ores of tin and copper. They all traverse the killas or other bedded rocks, and when granite is encountered in their course, they cut through that also, although no lead deposits of value have ever been found in the fissures within a mile or more of that rock, while the best lead lodes do not come near the granite.[1] With few (but notable) exceptions, the lead lodes are cross-courses running nearly north and south, and generally they underlie steeply to the eastward. The galena, which is their most important constituent, is nearly always argentiferous to a notable extent. Oxidised lead compounds are frequently present in very beautiful forms in the shallower portions of the lodes; blende and copper sulphides are often found in considerable quantities, while antimonial sulphides are not rare, particularly in East and North Cornwall. Quartz (sometimes saccharine, often chalcedonic) and fluor-spar are the commonest veinstones, but carbonate of iron is not infrequent. Brecciated structure is extremely common, and combed structure still more so. Our last President, twenty-five years ago, summarised the history of the formation of the lode at Wheal Mary Ann as follows:—

1. Formation of a fissure and fault. This left open spaces, which became more or less filled with fragments falling from the walls.

[1] See Plate I.

2. Deposition of chalcedonic quartz, especially on the footwall, as also in the minor interstices of the fallen fragments.

3. Deposition of quartz, galena, chalybite, calc-spar, fluorspar; there having been "at least two periods of formation of fluorspar; the lead was deposited at an intermediate period, and the last minerals have been quartz, chalybite, and calcspar."[1]

From the observations of Mr. Giles and others, it may be added that both barytes and pyrites were introduced into the lodes later than some at least of the galena. With very small and merely local differences, I believe this has been the history of all the lead veins in the West of England.

As to the period of the various movements, I have elsewhere argued that the first opening of the greater cross-courses was later than the formation of the greater tin lodes such as those on either side of Carn Brea Hill, and also later than that of the principal copper lodes of East Cornwall; while the second opening was probably later than the formation of the *newest* tin and copper lodes.[2] I have suggested that these last earth-movements were post-Cretaceous,[3] and I am pleased to note that Mr. Hill also considers them to have been formed in the early Tertiary period.[4]

[1] Foster, *Trans. R. G. S. C.*, ix. pp. 155–7.
[2] "Ore Deposits," *Journ. R. I. C.*, xliv. pp. 205 *et seq.*
[3] *Ibid.*, p. 222.
[4] *Trans. R. G. S. C.*, xii., 1901.

Sources of the Lead Ore in the Lodes.—Among those who have studied the subject it is universally agreed that the granitic masses in the West of England are intrusive, and that their intrusion has in some way supplied the tin which is now found in the lodes; a similar origin has been usually and with great probability assigned to the copper of the main copper lodes. It is probable, too, that much of the pyritic material, whether arsenical or not, had a similar origin; while the iron oxides, which are found so abundantly in many of the tin and copper lodes, are probably secondary products resulting from the oxidation of the sulphides.

But the lead in the lodes and cross-courses, and probably, too, the blende and carbonate of iron which are so often found associated with it, seem at first sight to have had a different origin. This will appear from the following considerations.

The "rich parts" of tin and copper lodes, when not actually in the granite, are rarely, if ever, found outside what has been called by Ste. Claire Deville "the granitic penumbra,"[1] while the rich parts of the lead lodes are never found within that highly altered zone.[2] Moreover, a great deal of the evidence goes to show that the deposition of tin and copper in the E. to W. and Caunter lodes had practically ceased before the N. to S. fissures began to receive their lead contents, and probably before

[1] The "metamorphic aureole" of Mr. J. B. Hill (*Trans. R. G. S. C.*, xii. p. 7).

[2] It will probably be found that this generalisation is true of nearly all lead veins in the neighbourhood of intrusive granite.

they were fully formed. Whence, then, came the lead now formed in these fissures? Was it from above? from the surrounding rocks? or from below? Some (though probably insufficient) grounds for an acceptance of Sandberger's "lateral secretion" hypothesis may perhaps be found in the cases of tin and copper; for traces of these metals, together with chlorine, fluorine, and boron, are undoubtedly present almost everywhere within the metamorphic aureole, which with the granite itself forms the country for these metals. But as regards lead the case is different; for, in the first place, while it is true that few analyses of apparently unaltered killas from the near neighbourhood of lead lodes have been made, or at any rate published, those few do not show the presence of lead.[1] It has been elsewhere shown that some copper was present in the stratified rocks before the basic intrusions took place, or else was introduced into them by those intrusions. Also that in all probability tin was present in some of the stratified rocks before the acidic intrusions were completed.[2] It is perhaps in itself not unlikely that the stratified rocks also contained lead in minute proportions.[3]

But even if analysis did show the presence of

[1] Here is a useful field of investigation for research students in our Cornish mining schools.

[2] See "Ore Deposits," *Journ. R. I. C.*, 1890–4.

[3] The absence of lead in the published analyses of course means little, for even though that metal were really present in small quantities, it might not be detected by the ordinary methods of analysis usually adopted.

lead compounds in the "country," it would not necessarily follow that the lead of the vein-filling had come directly from thence, and particularly so if the lead was not found at considerable distances from the vein or its ramifications, for it is obvious that a vein filled with lead solutions could impregnate the "country" in its near neighbourhood, and probable that it would do so.

Still, assuming its presence in the "country," it is possible to believe that the lead (zinc, etc.), like many of the "veinstones," *may* have come from thence into the lodes, either "laterally" from the rocks now existing, or by downward infiltration from rocks which once existed at a higher level, but which have been since removed by denudation.[1]

Doubtless a great deal of rock has been so removed, but there is certainly no positive evidence which goes to show that it contained lead, still less that it supplied the galena, etc., to the lead veins *per descensum* before its removal; and notwithstanding what has been written of other lead districts,[2] it must be regarded as very doubtful as regards the West of England. I admit the general

[1] Such veinstones as calcite and chalybite have pretty certainly been derived from the "country" in many instances, and even vein quartz has frequently had a similar origin. Chalcedonic quartz and fluor, however, seem more likely to have come from below.

[2] "In the observed veins of the [Monte Christo, Washington] district there is a rough succession from the surface downwards of galena, blende, chalcopyrite, pyrite, and arsenopyrite (mispickel) . . . . Upon various grounds it has been concluded that the upper sulphide zone, which contains the richest ore, was deposited, largely at least . . . by downward-tending waters. This conclusion involves the derivation of the lead ores from the surrounding rock. The lower

existence of mineral particles disseminated through most rocks, and I am ready to believe that if our analyses are made with sufficient care they will be found in all rocks. I also admit that these particles are liable to be dissolved out by the circulation of natural waters, to be transported from place to place, and to be redeposited when suitable situations and conditions are met with. But with all this I am unable to find any evidence that such has been the mode of formation of the lead veins in Cornwall. I am much more inclined to believe that the lead (and zinc) have come from the same deep-seated source as the tin and copper, but that it was later, and deposited only after travelling farther from that source. My hypothesis, which is partly geological and partly chemical, may be briefly stated as follows:—

(1) In West Cornwall the main foldings of the strata were produced before the Devonian period. In East Cornwall there is no evidence which would lead us to a similar conclusion. During the deposition of the Devonian rocks in this region, however, there were many basic intrusions, and even some active volcanoes, as may be seen clearly to the north of the Bodmin granite. A later series of

sulphide zones afford less evidence as to their origin, but what there is tends in the same direction . . . the general suggestion is deduced that all the zones were precipitated, in part, simultaneously by downward percolating waters, the different belts of minerals being precipitated in order according to their relative solubility" (Spurr, *Twenty-second Annual Report U.S. Geological Survey*, Part II.). This succession could, I think, be explained quite as well and probably better by my hypothesis.

earth-movements produced the east and west folds, which characterise East Cornwall and the whole of Devon. These probably culminated in the long series of acidic intrusions, granite and elvan.

(2) Beneath the granitic eruptives there is (as indeed is probable in many other mineral regions) a deep-seated and widely spread body of rocks, rich in complex metallic sulphides, accompanied by much chlorine, fluorine, silicon, and boron in various forms of combination, as also by much carbonic acid and very highly heated water. The intrusion of the granite was accompanied and followed by abundant evolutions of these compounds, producing first the metamorphic aureole; and later, as the rocks became fissured by cooling, contraction, and the force of gravity, the lower parts of the fissures received deposits of copper sulphide, tin oxide, and schorl, while their upper portions, now denuded away, received deposits of lead and zinc.

(3) But the granite, which was originally one great ridge, or group of ridges (not, of course, reaching the surface), now forms separate bosses because great sections of "country" have been let down hundreds and perhaps thousands of feet by repeated movements in connection with the great cross-courses[1] (xx., Fig. 1, Plate II.).

[1] The number of cross-courses, lead-bearing and otherwise, is very great, and as they nearly all have an easterly underlie, their general effect has been to drop the ground to the eastward. But there are some which dip to the westward, and these have facilitated a trough-like drop of the ground between the granite masses.

(4) These cross-fissures, like the earlier E. to W. fissures, at once became filled with mineral solutions rising from great depths, and consequently very hot and under great pressure. As the solutions rose in the fissures, and lost temperature and pressure, they deposited at first oxide of tin, then sulphides of copper and iron, and, still later, sulphides of lead and zinc and carbonate of iron—the first-named nearest to, the last-named farthest from, the source. Probably quartz in abundance was deposited all the time and everywhere.

(5) The rate and character of the deposits would not only be influenced and determined by variations of temperature and pressure, but also by the character and condition, physical and electrical, of the rock-surfaces or of the fragmentary materials already partially filling the fissure. The result of all this is that while a vein is in the granite tin usually predominates; when it enters the "aureole" copper is present with, or may altogether replace, the tin. Outside the aureole we may expect to find lead, galena, and blende. If this hypothesis be well-founded, the first complex solution must have contained, besides most of the ordinary metals, chlorine, fluorine, boron, silicon, sulphur, and carbonic acid. Gradually, as it cooled down and as it neared the surface, groups of combinations of these substances were deposited, until at last the exhausted solution issued from some convenient outlet as a chalybeate or alkaline spring. Furthermore, as might naturally be expected, there

are poor, unproductive or non-payable, zones between the payable zones, since the physical conditions—temperature, pressure, etc.—most suitable for the deposition of the various metals would not be likely to occur so as to form a continuous series of deposits.

Of course, the original deposits of the various minerals have been greatly modified by secondary solution and redeposition, from above downwards, and also laterally along the fissures, so giving rise to local accumulations, enrichments, and impoverishments; but in the main the original zones of deposition are unaltered.

Few of the lead lodes referred to in this paper have been followed down more than 200 fathoms, and none more than 350 fathoms from surface, so that, considering their position with reference to the exposures of granite at surface, there is no reason to believe that the region of the metamorphic aureole (granitic penumbra) has in any case been at all nearly approached; indeed, it seems probable that a borehole put down, say, at Wheal Mary Ann or at East Wheal Rose would not reach the granite in 1,000 fathoms of depth. It seems most likely that such a borehole, after leaving the rich lead shoots, would pass into a comparatively poor zone containing both lead and copper sulphides, then into richer copper sulphides without lead, then into a comparatively poor zone containing copper and tin, and finally into ore containing abundance of tin and

schorl, as in the case of the mines in the neighbourhood of Carn Brea.

It would be difficult, perhaps impossible, to follow a lode down by such a borehole, but a determination, by boreholes sunk in the "country," of the actual depths at which the metamorphic aureole and the granite respectively exist in the regions between the granite bosses would be of immense scientific interest, and might prove to be of great economic importance.[1]

Statistics and Future Prospects of Lead Mining in the West of England.—According to the "Mineral Statistics," supplemented occasionally from other sources, Cornwall produced, from 1845 to 1886, when lead mining practically ceased in the West of England, no less than 251,813 tons of lead ore containing 5,721,153 ounces of silver, and during the same period Devon yielded 59,236 tons of lead ore containing 1,341,597 ounces of silver, or together, 311,049 tons of ore and 7,062,750 ounces of silver. These statistics are avowedly defective, and very largely so in the early years, so that we shall be quite safe in reckoning on a total output during the period of 350,000 tons of ore containing 280,000 tons of lead and $7\frac{1}{2}$ million ounces of silver. But the mining of silver-lead ores had been going on for 600 years previously, and perhaps longer, some of the mines having been rather extensively wrought,

[1] There would be little difficulty in getting several such holes put down were Cornwall New South Wales; as it is I do not see much prospect.

and very rich in silver. There were, it is true, long periods of depression, during which very little lead or silver was wrought, as, for instance, in the early part of the nineteenth century.[1] Still, we ought probably to reckon that the output of the six centuries was at least as great as for the period 1845–86, and this would bring up the total lead to 560,000 tons and the contained silver to 15 million ounces. A moderate estimate of value would be 11 millions sterling.[2] All this mineral has been obtained from a total length of workings which can hardly have exceeded 20 miles, of an average width of 4 feet and an average depth of 100 fathoms. Of this explored lode-area probably one-half was left unworked, as pillars or sections too poor to pay cost. From these data, which can, of course, only be roughly approximate, it would appear that 586,667 cubic fathoms of ground have yielded 560,000 tons

[1] In 1835 only 140, and in 1836 only 180 tons of ore were obtained from all the mines. In 1837 only about a dozen mines were producing lead ore, viz. Wheal Betsy, North Wheal Tamar (between Launceston and Tavistock), a mine to the west of Lamerton, Combe Martin, Treburgett, a mine near St. Merryn, Wheal Rose (Newlyn), Wheal Hope, Goonhavern, in Perranzabuloe, Wheal Rose (Sithney), Wheal Penrose, Wheal Unity, and Wheal Saturn, near Porthleven (De la Beche, *Report*, p. 611).

[2] I have elsewhere estimated the quantity and value of the tin and copper ores raised from the lodes of the West of England (excluding in this case the stream tin) as under:—

Black tin, 1,250,000 tons, of an estimated value of £62,500,000
Copper ores, 11,500,000 „ „ „ £69,000,000

(see "Seven Centuries of Tin Production," *Trans. M. A. and Inst.*, 1892; "Four Centuries of Copper Production," *ibid.*, 1895; and "Origin and Development of Ore Deposits," *Journ. R. I. C.*, 1895).

of dressed lead ore, or, say, 5 per cent. of the total weight of ore-ground excavated.

In the foregoing pages it has been sufficiently set forth that the mining of lead and silver has been an industry of importance, and one very naturally asks, now that it has been at a standstill for a good many years, Is it dead, or only sleeping? Time alone will show. Against the future of lead mining in the West of England may be urged the following:—

(1) That for various reasons, among which difficulties of tenure and of royalty loom large, it is practically impossible to obtain capital for working any west-country mine.

(2) That the mines of the future must be in general of considerable depth, and therefore relatively costly to work.

(3) That the ruling prices of lead, and latterly of silver, seem to have settled down to too low a level for the profitable working of ordinary fissure lodes.

On the other hand, in favour of the future working of these deposits may be reckoned:—

(*a*) The great improvements in modern mining, dressing, and smelting methods, whereby production has been greatly cheapened.

(*b*) The growing probability that there will be by-and-by a considerable and continued rise in the price of lead, and perhaps even of silver.

(*c*) The expectation that in the near future means will be devised whereby the mineral riches of the west country will be secured by working

extensive districts rather than individual mines. In such cases great central pumping establishments will deal cheaply with the underground waters, while the ores will be brought by straight and level roads to convenient hoisting centres, and there raised through good shafts by powerful engines to fully equipped dressing-floors, adequately supplied with well-arranged labour-saving machinery of modern type and worked under skilled supervision, chemical treatment being also employed in the case of complex ores when necessary, so as to obtain products as rich and pure as possible for the market.

Worked under such conditions, if they can be secured (and it is hard to believe that they will be for ever out of reach), it does certainly seem that it is not very rash to prophesy still another prosperous period for mining, and even for lead and silver mining, in the west country.

NOTE ON THE *FAUJASINÆ* OF THE TERTIARY BEDS OF ST. ERTH.

By Fortescue William Millett.

In the *Transactions* of this Society for the year 1896 there appears a paper by myself bearing the title, "The Foraminifera of the Pliocene Beds of St. Erth, in relation to those of other deposits." In this paper, after giving various instances of the resemblance between the foraminifera of St. Erth and those of the Italian Tertiaries, at page 45, I speak of the genus *Faujasina*, which on the authority of O. G. Costa is stated to occur in two localities in Italy, and give various reasons for refusing to accept Costa's determination of the genus, adding, "It would be rash at present to accept Costa's form as evidence of a resemblance between the St. Erth and the Italian foraminifera. Dr. Fornasini is now engaged in the useful work of revising Costa's determination of species from the original specimens themselves, and it is to be hoped that some day he will be able to enlighten us on this particular subject."

Following this, Dr. Fornasini with his usual courtesy undertook the quest of Costa's original specimens, and the result appears in his paper, "Le pretese 'faujasine' di O. G. Costa," published in the *Rivista Italiana di Paleontologia*, anno viii., fasc. 1, 1902.

He states that after a long research Professor Bassani, of the University of Naples, had succeeded

in finding in the Geological Museum the material required. This consisted of three glass tubes, each labelled "*Faujasina*," in Costa's own handwriting. On examining the contents of these tubes, Dr. Fornasini found that in one of them the specimens were nothing more nor less than *Polystomella crispa;* another contained examples of *Anomalina arimenensis;* whilst in the third was a solitary *Operculina ammonoides.* Thus, thanks to Dr. Fornasini, the mystery of Costa's "*Faujasina*" has been cleared up in a satisfactory manner.

In the *Revue Critique de Paléozoologie* for October, 1902, at page 218, M. Dollfus, in reviewing Dr. Fornasini's paper, makes the statement that in 1896 I relied upon the presence of *Faujasina carinata* in the St. Erth beds to show the affinity of that deposit with the Pliocenes of Italy. He then goes on to intimate that Fornasini having shown that Costa's determination was completely wrong, the Tertiary hypothesis is untenable, and he proceeds to express the opinion that the *Faujasinæ* of St. Erth proceed from a deposit of the Upper Chalk which existed in Cornwall in the Pliocene period, and has since been completely removed by denudation!

This misapprehension of M. Dollfus is the more inexplicable since in the very work he is engaged in reviewing Dr. Fornasini distinctly states that I produced other evidence of the relationship between the foraminifera of St. Erth and those of the Italian Tertiaries, and that I refused to accept Costa's determination without further evidence.

Mem.—In the footnote of my 1896 paper the date "1885" should read "1895."

Royal Geological Society of Cornwall.

THE NINETIETH

ANNUAL REPORT

ETC.

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1904.

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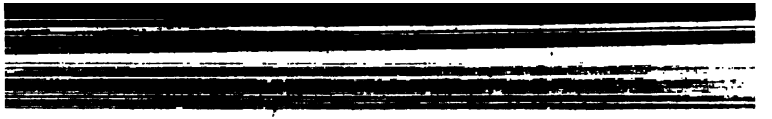

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ANNIVERSARY ADDRESS OF THE PRESIDENT,

J. H. COLLINS, Esq., F.G.S.

To the General Meeting, October 27th, 1903.

Ladies and Gentlemen,—I feel it a great honour that I have been chosen to preside over this ancient and important Scientific Society, and to succeed so eminent a series of Presidents in the occupancy of this chair. Not to speak of those Presidents of recent years who are, happily, still with us—when I think of such men as Davies Gilbert, Sir Charles Lemon, Charles Fox, and Warington Smyth—when I recall the distinguished positions held by many of my predecessors, the scientific eminence of some and the eloquence of others, I feel a chastened pride that it has fallen to me to sit in their seat in order that I may, to the best of my ability, help to carry on their work.

The many papers on the stratigraphy, mechanical deformation, chemical metamorphism, mineralogy, petrology and palæontology of our peninsula which have appeared in our *Transactions*, in the *Quarterly Journal of the Geological Society*, in the *Journal of the Royal Institution of Cornwall*, and in the *Mineralogical Magazine* since the publication of Sir Henry Delabeche's classic report nearly seventy years ago, have paved the way for that general correlation which may reasonably be expected as a result of the renewed Geological Survey which is now in progress. In particular it is to be hoped that, in the interest of the miner, the position of the principal lodes at sea-level and at successive stated depths below that level will be laid down on the 25″ maps, and published, after reduction, to the 6″ scale. Meanwhile there is a wide and useful field open for the individual labourer, particularly in fossil-hunting. During the last few years very important palæontological discoveries have been made. I need only men-

tion the surprising pliocene fauna of St. Erth and the numerous fossils found by Messrs. Howard Fox, Upfield Green, and others during this second period of fossil-hunting, including the several species of pteroconus, the somewhat numerous cephalopods, and the traces of the remarkable fishes—Pteraspis, Phlyctanaspis, Cephalaspis, and Climatius. These fishes with strange names belonged to a type which is now practically extinct; they had cartilage only for the internal skeleton, and they were covered with a strong armour composed of separate beautifully fitted and delicately sculptured bony plates, armed in some cases with strong spines.

I may here remark that it is especially desirable that search should be made for fossils along the north coast, west of Perranporth, and in the Mount's Bay between Marazion and Gunwalloe Cove.

The leading features of our Museum deserve to be more widely known than they are at present. The great success of the Society from the very first, and the liberality of its members and friends in presenting specimens, has made it necessary to secure additional accommodation from time to time. The question of a site for the present building was discussed as far back as October, 1850, and in the year 1863 the ground on which we stand was presented by Miss Elizabeth Carne as a memorial of her distinguished father. Very wisely it was resolved to have a building worthy of this fine site, and after considerable discussion it was decided to co-operate with other public bodies; the result is seen in this magnificent building, of which the foundation-stone was laid by Mr. Charles Fox on the 28th of April, 1864. Since the completion of the building much labour has been expended by the various curators and others in arranging the collections as they are at present. We now possess a good collection of minerals, very largely Cornish, and a fairly complete general educational fossil collection. But, beyond this, there is the unique collection of local fossils, which, in addition to the very numerous palæozoic examples, includes a remarkable series of remains from the tin stream works and associated quaternary deposits; and, thanks to Mr. Fortescue

Millet, an extensive collection of shells from the pliocene beds of St. Erth.

It should be more widely known than is at present the case that the Museum is open to all comers, and without charge, at all reasonable hours. It has, to my certain knowledge, been most useful, not only to members of the Society, but to students generally, who have been encouraged to record their observations in the mines and elsewhere, and frequently aided in so doing by small money grants. In connection with the Museum, too, the Society has rendered most valuable assistance at critical times in the establishment of science classes, and has also contributed to their maintenance for a series of years.

While on the subject of the Museum I cannot help expressing my regret that it was not possible to acquire the beautiful Carne collection, so as to keep it in what may be called its native air. The greater part of the important Caerhayes collection has been retained in the county—thanks to the liberality of its owner, Mr. John Charles Williams, and, more recently—as a result of the generosity and public spirit of one of our past-Presidents, and of the enterprise of the Royal Institution of Cornwall—the almost unique Rashleigh collection has been established at Truro. We cannot help wishing that we had been able to secure one or other of these collections for this Museum, but as that was impossible, we rejoice at the good fortune of our neighbours.

The Bolitho Medal, founded by means of a substantial legacy left by Mr. William Bolitho, jun., our esteemed Treasurer for a long series of years, has already been awarded by the Council on several occasions. The awards hitherto made have been much appreciated, and I am proud to have been one of the recipients. The prospect of such awards cannot fail to act as an incentive, if not to study and labour, yet to the publication of the results of such labours; and to-day it has been a great pleasure to me to hand the medal to my old friend Mr. W. A. E. Ussher, whose researches into the phenomena of the submarine forests, raised beaches, blown sands, and other quaternary deposits of the West of England, and his later investigations among the car-

boniferous and other palæozoic rocks of the same district are well known to, and highly appreciated by, all of us.

It is a matter of great satisfaction to this, the senior Scientific Society of Cornwall, to witness the vigorous and useful lives of its younger sisters—the Royal Institution of Cornwall, the Royal Cornwall Polytechnic Society, and the Penzance Antiquarian Society. The many efforts that have been made to secure a sort of federal union of these Societies have hitherto met with no success, yet there are those—and I am myself of the number—who still hope that this lies in the lap of the future.

We cannot fail to recognise with satisfaction the useful and important educational work done by the Camborne, Redruth, Truro, and Penzance Mining Schools, offshoots, as they are, of the Miner's Association founded more than forty years ago by Mr. Robert Hunt, whose memory is dear to many of us here present. We have no occasion to blush for the mining work of our "Cousin Jacks." If at home they are somewhat slow in taking up and applying new inventions and new methods, it is much more from want of money than from any lack of brains or enterprise, and we may reasonably exult in the fact that at the present moment a considerable proportion of the leading mines and reduction works of the world are controlled, either as managers or foremen, by Cornishmen who have been trained in the old county.

During the life of the Society mining generally, and the mining industry of Cornwall in particular, has experienced many changes. Copper-mining, already an important industry in the West of England in the earlier years of the nineteenth century, increased until it reached enormous proportions, and has since shrunk into almost insignificance. The much older tin-mining industry has, on the whole, flourished in spite of extraordinary discoveries and developments in the East Indies, in Australia, and in Bolivia.

Lead-mining, once of great importance in the West, has now come to an end. The mining of iron and zinc, arsenic and wolfram, had from small beginnings increased to considerable dimensions, and has now once again become almost extinct.

But the working of china-clay and china-stone has, to some extent, restored the balance, so that the total mineral production of the West of England at the beginning of the twentieth century compares very favourably with the similar total of 1801, although the number of persons employed in connection therewith has very greatly decreased.[1]

The improved winding appliances; the introduction and abandonment of the man-engine; the employment of wire-rope instead of chain or hemp-rope, making the safe use of skips possible; the now universal use of safety fuse; the general substitution of "high" for "low" explosives; the introduction of boring machinery; the improvements in ore-crushing and dressing machinery—all these are well within the memory of some who are still among us. One need only mention the Blake stone-breaker, the Californian and Husband stamps, the revolving frame, the Frue Vanner, and the Wilfley table, to show the contrast between now and then. Some of those present may have seen the new oil process in operation at Tywarnhaile; if so, they must have been surprised at its unexpected and scientifically, and it is to be hoped commercially, successful results. I say "unexpected," because it was not to be foretold that by mixing oil and water, mineral and veinstone together, the light oil should float up, so to speak, the heavy ore material and leave the lighter veinstone behind. It is unfortunate that so far the process has proved itself entirely inapplicable to the treatment of tin ores.

The great success, at the Clitters mine, of the Wetherill magnetic machine for separating tin and wolfram is also worthy of notice, and should serve as an object-lesson in other quarters.

We have seen with great regret the abandonment of mining

[1] At the close of the eighteenth century the annual value of the minerals raised in Devon and Cornwall was something under three-quarters of a million sterling; about the middle of the century it was nearly one and three-quarter millions; it is now over one and a quarter millions. In 1902 the productions and value were as under :—

	Tons.	Value.
Metallic Minerals . .	17,451 ...	£551,961
Non-metallic Minerals . .	1,816,145 ...	678,819
Total . . .	1,834,296 ...	£1,230,780

throughout whole districts and the practical withdrawal of most of our local magnates from mining pursuits. Yet we know that very few, if any, of the great lodes have been really exhausted, and we may still hope that a time will come when, with larger organisations, possessed of capital sufficient to enable them to live through periods of low prices, to work on an extended scale, and to provide modern machinery and appliances, most of these abandoned districts may be again busy mining centres. And one cannot help seeing that the coming of the good time will be hastened if the owners of mineral lands generally can be brought to see, as some have seen already, that it is not only their interest, but also an absolute necessity, if home mining is to continue, that all mining leases should contain a provision that dues shall not exceed a reasonable proportion of profits, and that when there are no profits there shall be no dues. Unless some such arrangement becomes general, I am sure that the considerable capitals required for properly working deep mines will not be forthcoming. Difficulties, of course, there will be, in the future as in the past, especially as the mines hereafter must be of great extent, and so will often occupy ground belonging to many "lords"; but, with real knowledge of actual conditions and with goodwill, it is to be hoped that these difficulties may be got over. The lease of East Pool is in more reasonable form than most previous leases; and the more recent grant to Wheal Grenville approaches still more to what may be considered fair and reasonable between the "adventurer" and the "lord."

Dr. Haldane's report on Ankylostomiasis, the disease comparatively new to Cornwall which recently appeared among the miners in Dolcoath Mine, has been received with much satisfaction. The disease seems particularly to flourish in mines where the temperature is high, the air moist, and where no special sanitary arrangements have been provided. Fortunately it has been found to be very amenable to treatment. The management at Dolcoath has been prompt in action, both preventive and curative, and we may therefore expect, with some confidence, that the disease will not only be prevented from spreading, but even altogether eradicated before long. In other

ways steps have been taken recently with a view of protecting and preserving the health of the miners. They will not use the respirators which have been designed to prevent the inhalation of dust while working the now so generally used boring machines, but it has been found that a properly arranged water-spray suffices to prevent all mischief from the dust produced in boring, and at the conference recently held at Dolcoath mine it was resolved to use the water-spray apparatus wherever it might be found necessary.

Very great extensions of tin-mining have taken place in the East Indies, Australasia, and Bolivia during the life of this Society, and quite recently important discoveries have been reported from South Africa and Alaska. Equally important has been the growth of copper, lead, iron, and zinc mining, as also of diamond-mining; in fact, most of the great mines of these ores, which are now working throughout the world, have been developed during the lives of those now present in this room. The same may be said of the great discoveries of gold in Australasia, in North America, in India, and in South Africa, so that millions are now invested in mining where thousands formerly sufficed, while mining investors have probably increased a thousandfold in number. It is perhaps not much to be wondered at that these great colonial and foreign mining enterprises, and especially those which offer the glamour of gold and diamonds, should secure the attention of speculators who would otherwise adventure in the West of England. Yet I cannot think that one of the very best mining regions of the world, possessed besides of extraordinary climatic and other advantages, will be permanently overlooked, as it has been for some years past. Already I think we may see a change in this respect. Prospecting in the West of England is just now being carried on more actively than for some years past, and foreigners are coming in to open up ore-deposits which have been long neglected by the natives. Such operations must be good for the old country, and I, at least, will wish the foreigners success.

A good deal has been said in the newspapers of late about the electrical ore-finding appliances devised by Messrs. Daft and Williams, and which are now being operated abroad by a

gentleman whose name is well known in Cornwall—I refer to Mr. Ernest Lidgey. This apparatus—the telephonic dowsing-rod, as it has been called—is of a much more elaborate and costly character than that used by Mr. Robert Were Fox seventy years ago, but in many respects it works on the same lines. Great things have been said as to the achievements of this new method in North Wales and elsewhere, but it seems, from an authoritative letter which appeared not long since in the *Mining Journal*, that these achievements have been somewhat exaggerated. Like Mr. Fox's method, this new system is probably capable of affording some indications of value at times, and its developments therefore deserve to be very closely watched. But we must not allow our wishes to bias our judgment; the mere discovery of a lode is of little moment, for in all mineral districts lodes of a sort are common enough. The difficulty is, and always has been, to find ore-deposits, or "rich parts," in lodes that will pay to work. And according to the letter above referred to, the reported discovery at the Cwmystwith mine, of which so much has been made, has not proved to be of workable value. I therefore think it will be advisable to wait and watch, and to keep an open mind on the subject, especially as the inventors themselves do not claim that it is at present applicable to tin-mining. I wish it were otherwise, for we sadly need some means of discovering the many unlocated carbonas which must undoubtedly exist in the St. Ives district, and probably also in the Wendron and some other granite districts.

In conclusion, though with some diffidence, I feel that I must touch on a question which is partly political. I am certainly no Socialist, at any rate in the ordinary sense of the term, but I cannot help seeing that it would be a good thing for the county and for the mineral owners themselves if the whole of the mineral rights were to be purchased by the local authorities or by the State. Individual ownership was well enough when mining was practically confined to the surface, but now that we have to deal with great depths, the extensive drainage operations and explorations which are absolutely necessary in order that the mineral resources of the county shall be properly and economic-

ally utilised, are rendered almost impossible under the present system of individual ownership. Fair and even liberal compensation should of course be paid to the owners of the mineral rights for their surrender, and I do not doubt that most of them would quickly see how advantageous such a surrender would be to them, but, of course, any individual objector would have to be dealt with as similar objectors are dealt with under railway, road, canal, or harbour Acts.

I hope, ladies and gentlemen, that I have not quite exhausted your patience with these somewhat discursive remarks; they have, at any rate, a direct reference to what is still a great county industry. My desire has been to sum up, as it were, the progress of recent years, and to suggest lines of thought and action for the future. If I have at all succeeded in this I shall not have occupied your time in vain.

In presenting the Bolitho Medal to Mr. W. A. E. Ussher, the President said:—

I am very glad that it falls to my lot to present the William Bolitho Medal on this occasion to an old friend who has worked much on the elucidation of our West-country Geology, and who has enriched our *Transactions*, among others, with his communications;[1] and in particular we have to thank him for his interesting summary of the superficial Geology of the West of England, which was privately printed in the year 1879.

Mr. Ussher, in presenting you with this medal I have to assure you that the Council feels that it could not possibly carry out the wishes of the founder in any better way than by recognising your long geological labours in the West Country.

[1] The following papers by Mr. W. A. E. Ussher have appeared in our *Transactions*:—

"Recent Geology of the Cornish Coast near Padstow." Vol. x. p. 58.

"Pleistocene Notes on the Coast between Plymouth and Looe." Vol. x. p. 63.

"Devonian Rocks between Plymouth and Looe." Vol. x. p. 70.

"Devonian Rocks as described by De la Beche, Interpreted by Recent Research." Vol. xi. p. 273.

REPORT OF THE COUNCIL

To the Annual General Meeting, October 27th, 1903.

THE Council are pleased to report to the members, in this the Ninetieth Annual Report, that the premises and property of the Society are in good order, both the Museum and the Library having received additions during the past year.

The Museum has been largely visited by the public, no less than 230 names being written in the visitors' book; and in addition the Council are glad to say that the collections of the Society have been made use of by the students of the Penzance Mining Schools and by the pupils of the West Cornwall College.

The work of the new Survey of Cornwall has been continued with energy and thoroughness during the year, in continuation of that done in 1902, of which an interesting report is published in the official *Summary of Progress* for 1902. A large part of the central and west central portions of the county have been already carefully examined by Mr. Reid and the officers of the Survey, and at present Mr. Reid is engaged in working at the extreme west.

The Society should again call the attention of residents in the county to the opportunity of helping the surveyors in their work, either in the field, or by the communication of information or the exhibition of specimens, which may be done, if necessary, through the officers of this Society.

The information contained in the plans of the abandoned mines will be of the greatest service, and the Council appeals to all persons who may have any of these in their custody to allow the examination of them by the surveyors. Any persons who have plans which they may be willing to lend for this purpose

may forward the same to the Secretary of this Society at the Museum, where they shall be carefully preserved and returned, if required, in due course.

The Council regret to record the death of Mr. W. E. Baily, F.L.S., of Lynwood, Paul, who was for some years a member of the Council.

The Council have decided to award the William Bolitho Gold Medal for 1903 to W. A. E. Ussher, Esq., F.G.S., of H.M. Geological Survey, feeling confident that the whole body of the members will cordially support their conclusion that his attainments and labours in geological science, especially in the county of Cornwall, and his contributions to the publications of this Society, have thoroughly deserved the recognition.

They recommend the election of Mr. T. G. Bonney, LL.D. F.R.S., etc.; D. A. Smith Woodward. LL.D., F.R.S.; F. A. Bather M.A., D.SC.; and Mr. G. C. Crick, F.G.S., as honorary members o this Society.

LIBRARIAN'S REPORT.

1903.

THE Librarian acknowledges with thanks the receipt of publications from the following:—

American Geographical Society.
—— Academy of Arts and Sciences.
—— Museum of Natural History.
—— Philosophical Society.
Batavia. Jaarbock van het mignwezen in Nederlands oost Indie, 1902.
Belgium. Société Géologique.
Berlin. Zeitschrift für practische Geologie von mar krahman.
British Association.
Buenos Aires. Museo Nacional.
Canada. Government Geological Survey.
——. Royal Society.
Canadian Institute.
—— Record of Science.
Cape of Good Hope. Department of Agriculture.
Cincinnati. Society of Natural History.
Colorado. Scientific Society.
——. College.
Cornwall. Royal Polytechnic Society.
——. Royal Institution.
Dorpat. Naturforscher Gesellschaft bei der Universitat Juyew.
Dublin. Royal Society.
Edinburgh. Geological Society.
——. Royal Society.

Elisha Mitchell Scientific Society.
Freiberg. Berg un Huttenwesen.
Geological Society.
Geologists' Association.
India. Geological Survey.
Iowa. Geological Survey.
Japan. Royal College of Science.
Kansas. Academy of Science.
Leicester. Literary and Philosophical Society.
Liverpool. Literary and Philosophical Society.
——. Geological Association.
——. Geological Society
London and West Country Chamber of Mines.
—— Geological Society.
Manchester. Geographical Society.
——. Geological Society.
——. Museum. Owens College.
Mexico. Instituto Geológico.
——. Mining Record.
Minnesota. Geological and Natural History Survey.
Montana. University.
Montevideo. Museo Nacional.
New South Wales. Royal Society.
New Zealand. Minister of Mines.
North of England. Institute of Mechanical and Mining Engineers.
Nova Scotia. Institute of Science.
Peru. Cuerpo de Ingenioros de minas.
Philadelphia. Academy of Natural Sciences.
Plymouth Institution.
Queensland. Government Department of Mines.
——. Government Mining Journal.
Rochester Academy.
Royal Society.
Smithsonian Institution.
South Australian School of Mines.
Toscana. Societa di Scienzi Naturali.

United States. Geological Survey.
Upsala. Geological Institution of the University.
Victoria. Secretary for Mines.
Vienna. K.K. Geologischen Reichsanstalt.
Western Australia. Department of Mines.
——. Geological Survey.

[*From the Authors.*]

The Volcanic Origin of Natural Gas and Petroleum. By E. M. Coste, Toronto.
The Influence of Winds upon Climate during the Pleistocene Epoch.
Late Tertiary History of East Anglia. By F. W. Harmer.
Report on the Foraminifera of the Malay Archipelago. Parts xiii., xiv. By F. W. Millet, F.R.M.S.
Index to De la Beche's Report. By Clement Reid, F.R.S.

[*Purchased.*]

Palæontographical Society. Vol. lvi., 1902.
London, Edinburgh, and Dublin Philosophical Magazine.

CURATOR'S REPORT.

DONATIONS TO THE MUSEUM.

By HOWARD FOX:—

Wax cast of *Homalonotus Barratti*, n. sp. (H. Woodward) from Mother Ivey's Bay [described with sketch, *Geol. Mag.* No. 463, Jan., 1903].

Wax cast of *Phacops latifrons* (?), Bronn, from the mainland opposite Trescore Island [described *id.*].

Slab of slate from Mother Ivey's Bay, containing:—

(*a*) Brachiopod allied to *Retzia longirostris*, Kayzer. [= *Terebratula ferita*, Sch.]

(*b*) *Orthoceras*, resembling *O. gracile.*

(*c*) *Tentaculites.*

(*d*) Crinoidal fragments.

Group of Gastropods, resembling *Euomphalus serpens* (Phillips) from Booby's Bay.

Tentaculites, possibly allied to *T. lævis*, from Booby's Bay.

Monticuliporoid Polyzoon (?) from Bedruthan.

Tabulate coral (?) from Gunwalloe fishing cove.

Sundry organisms „ „ „

"Sugary Quartz" from quarry of Hornblende Schist, half a mile north of Porthoustock.

Radiolarian Chert from Egloskerry.

Lithia Mica from Roche. Presented by H. Martin.

Gold in quartz from Evancore, North Italy. Presented by J. Peneluna.

Conglomerate (Trachytic Boulder) from "Bassick" Mine Colorado. Presented by R. Pearce.

THE WILLIAM BOLITHO GOLD MEDAL,

whioh is provided for by a fund bequeathed to the Society for the purpose by William Bolitho, of Ponsandane, in 1895, has been awarded annually to the following members :—

1896. R. Etheridge, F.R.S., etc.
1897. Howard Fox, F.G.S.
1898. J. H. Collins, F.G.S.
1899. F. W. Millet, F.R.M.S.
1900. Sir C. Le Neve Foster, F.R.S., etc.
1901. Thomas Clark.
1902. Dr. Richard Pearce.
1903. W. A. E. Ussher, F.G.S.

TREASURER'S STATEMENT, 1903.

Dr. *The Treasurer in Account with the Royal Geological Society of Cornwall.* **Cr.**

October 27th, 1903—	£	s.	d.
To Ordinary Subscriptions	46	4	0
,, Subscription per His Royal Highness the Prince of Wales for 1903	20	0	0
,, One Year's Dividend on £1,800 Midland Railway 2½% Debenture Stock, £45 0s. 0d., less tax, £2 12s. 7d.	42	7	5
,, Sale of *Transactions*	5	14	6
	£114	5	11
,, Balance due to Treasurer	48	2	5
	£162	8	4

October 26th, 1903—	£	s.	d.
By Balance from last year's Account	60	7	2
,, Water Rent	0	8	0
,, Curator's Salary	42	7	5
,, Fire Insurance Premium	2	12	9
,, *Transactions*, Periodicals, etc.	40	11	9
,, Coals and Gas	9	8	11
,, Repairs to Buildings	2	0	11
,, Stationery, Carriage, Postages, and petty disbursements	4	11	5
	£162	8	4
,, Balance due to Treasurer	48	2	5

PENZANCE, *October 27th*, 1903.

T. R. BOLITHO, *Treasurer.*

W. BOLITHO GOLD MEDAL ACCOUNT.

Dr.	£	s.	d.	Cr.	£	s.	d.
January 30th, 1904—				November 3rd, 1902—			
R. and S. Garrard and Co.	12	10	0	By Balance	514	7	8
Balance	514	19	8	October 27th, 1903—			
				Interest to April 15th, 1903	13	2	0
	£527	9	8		£527	9	8
				By Balance	514	19	8

LIST OF PAPERS

READ TO AND PUBLISHED BY THE SOCIETY.

1903.

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1. President's Address. By J. H. Collins, F.G.S.

2. Supplementary Notes on some Coast Sections in the Parish of St. Minver. By Howard Fox, F.G.S.

3. Geological Notes, No. 2. By Howard Fox, F.G.S.

4. A Trachytic Boulder. By Richard Pearce.

5. A Plea for the Study of Cornish Quaternary Geology. By Rev. D. Gath Whitley.

6. A Cross-Section and some Notes on the Tin and Copper Deposits of Camborne. By D. A. MacAlister.

THE SEVEN SOULS ROCK AND THE MOULS ISLAND, LOOKING NORTH FROM CLIFF CASTLE PROMONTORY.

To face page 747.

SUPPLEMENTARY NOTES ON SOME COAST SECTIONS IN THE PARISH OF ST. MINVER.

By Howard Fox, F.G.S.

(Read 27th October, 1903.)

Since the paper on the above subject was read last November, Mr. Parkinson joined me last month in going over this ground again, when we found some new points worthy of notice. Mr. Parkinson's petrological notes are not yet completed, as he has been appointed to an important post in Nigeria, and had to leave England immediately; but he hopes, on his return next summer, to send you some interesting matter connected with these rocks.

ROCK QUARRY.

On the first shelf of this quarry, opposite the entrance, the igneous rock is seen to weather in spheroids, with the slate adjoining much jointed and porcellanised. Mr. Parkinson had this altered slate analysed by Mr. Benedict Kitto, F.I.C., who found it to contain 6·42 per cent. of soda. A piece of the fine-grained igneous rock at the right hand on entering the quarry contained 3·42 per cent. of soda.

In the grassy slope above this quarry outcrops of the porcellanised slate, in contact with this igneous rock, can be traced to the top of the hill. It weathers white, and is in marked contrast to its surroundings.

DOOM BAR.

In the last paper, when speaking of the submarine forest in Daymer Bay and of Trebetherick Point, we omitted to refer to two interesting notices of this region. A very comprehensive pamphlet on "The Post-Tertiary Geology of Cornwall" was published, for private circulation, by Mr. W. A. E. Ussher, F.G.S., in 1879. This pamphlet is in your library, and is therefore accessible to your members.

Mr. Ussher devotes the latter part of his pamphlet to the pleistocene deposits of this special district, and he illustrates his descriptions with sketches. He also refers to a notice of this submarine forest by Mr. William Jory Henwood, F.R.S., published in the Fortieth Annual Report of the Royal Institution of Cornwall, 1858, in which Mr. Henwood writes as follows:—

"A layer of earth, sometimes mixed with—sometimes, for short distances, replaced by—clay, but always containing fragments of slate, rests on the rock; and where laid bare by the winds and waves, it can be traced from above high-water, below ordinary low-water mark, beneath the Doom Bar, without reaching its boundary in either direction. Where exposed to the elements it is seldom a foot in thickness, and is often much less.

"In this formation the roots of trees occur evidently *in situ*, as some of them spread as much as twenty feet horizontally; whilst portions of broken trunks have been found erect and protruding through the overlying sand. One of these, dug out just before my visit, was thought to be a yew tree. The remains of oaks—large enough, and still fit for use—have been from time to time obtained; thickets of hazel, their roots penetrating to the rock, surrounded by successive layers of leaves and nuts, alternately with thin beds of sand and earth, are found here and there; and the horns of red-deer have now and then been discovered amongst them.

"Whether trees so large as those discovered could have flourished in our climate on such shallow earth I do not know; but as the roots are sometimes found spreading on the surface of the earth and covered with sand, it seems probable that a portion of the soil has been swept off.

"The sand and earth overlying the vegetable mould are mixed with shells similar to those living on the adjoining sand-hills."

BROADAGOGUE COVE.

Similar colonies of sand tubes to those described in this cove were seen this autumn in great abundance, covering the outer rocks of the foreshore both north and south of Polzeath Sands, as also at Lundy Beach and elsewhere on the north coast of Cornwall. Professor Clark, D.SC., of Truro, determines their builders and tenants to be *Sabellaria alveoluta*, L.

CLIFF CASTLE PROMONTORY.

The Fig. No. 2, opposite page 671 of this volume, shows the portion of this promontory to which John Arthur Phillips must have alluded when he included among the "Blue Elvans" of North Cornwall "a dark green trap which at Pentire Point is interbedded with the vesicular lavas," and of which trap he gives an analysis, showing it to contain 2·61 per cent. of soda.[1]

The southern side of this Point ("Rumps Point" of the Ordnance maps) is the home of sea lavender, *Statice auriculæfolia*. The slate in contact with this igneous rock is, as elsewhere, porcellanised, and weathers white. The northern side of this Point is a scene of the utmost desolation, as the seas sweep these fantastically shaped crags bare of vegetation. The question arises whether this rock may not be the neck of the volcano which supplied the lava that composes the vast mass of Pentire Point and cliffs, as well as other prominent headlands to the eastward. This "Blue Elvan" is a doleritic camptonite, varying from fine to very coarse grained, and resembles the igneous rock of Rock Quarry.

The isolated portion of the cliff in the foreground of the photograph, of which the frontispiece of this paper is a reproduction, is the "Seven Souls Rock" of the Ordnance map, probably so called in memory of some shipwrecked mariners.

[1] *Quart. Journ. Geol. Soc.*, vol. xxxiv. p. 477.

The summit and the northern and eastern sides of this Rock are composed of igneous rock, the junction of which with the slates can be well studied from the adjoining cliff.

MARKHAM'S QUAY.

The light green rock referred to in our previous paper, page 673, as being igneous, is, in fact, an altered slate. At low-water spring tides we can easily examine it, and we can walk on sand from the western cliff of this cove to Epphaven, east of Lundy Cove. The rocks on the foreshore west of the sand opposite Markham's Quay are uncovered at extreme low-water, and are igneous.

EPPHAVEN COVE.

The igneous rocks of the foreshore on the west side of this beach, which become uncovered at extreme low-water, are well worth examination. They weather a speckled light green, passing into yellow-ochre colour; they are reticulated with joints and rusty-coloured veins, and their porphyritic crystals of quartz, etc., up to half an inch and more in length, frequently weather out prominently from the ground mass, which is polished smooth by the constant scour of the sand. In one portion of this rock there were inclusions of small angular fragments of indurated slate in close proximity to the crystals of quartz.

FOSSILS.

In addition to the fossiliferous beds mentioned in our last paper as occurring at Gravel Caverns and Com Beach, the dark blue slate of Epphaven has been found to contain many doubtful crinoidal remains, some small pyritised thorn-like bodies, and a minute starfish, discovered by Miss Barbara Legg.

Dr. F. A. Bather, of the British Museum, kindly examined them, and says :—

"I have worked carefully through all the specimens, but regret my inability to say anything about the majority. There are some possible fragments of crinoid stems, but not enough to swear to. The little thorn-like bodies, in some cases, at first sight resemble the Styliola from Booby's Bay, but in other cases seem to widen rapidly at the broader end, a fact that suggests to me spines of some starfish ; but this is quite doubtful.

"The little starfish is an Ophiuroid, and, so far as I can judge without more prolonged study, is either *Ophiurina* or a close ally. That genus occurs in the Lower Devonian of Germany. I need hardly say that we should be very glad to have this specimen, if agreeable to you. I could then attempt to describe it along with some other starfish remains which you were good enough to present, but which have been waiting further elucidation.

"Further cleaning of the apparent styliolæ shows that they have this structure a stronger central cone with side flanges. I don't know what they are."

GEOLOGICAL NOTES. No. 2.

By Howard Fox, F.G.S.

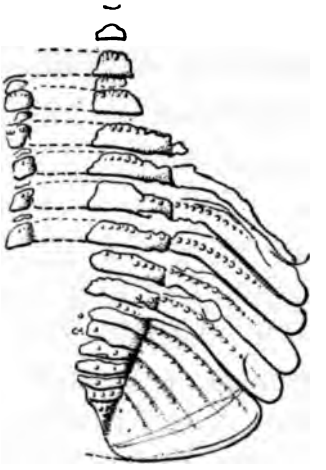
(Read 27th October, 1903.)

SUPPLEMENTARY NOTES ON THE DISTRIBUTION OF FOSSILS ON THE NORTH COAST OF CORNWALL SOUTH OF THE CAMEL.

Since the publication of the above paper in your *Transactions*, 1901, a very notable addition to the fossil fauna of this district has been made by Mr. Walter Barratt, of Newquay. He found in the blue slate of Mother Ivey's Bay a fragment of a new species of large trilobite. Dr. H. Woodward, F.R.S., published his description and sketch of this interesting fossil in the *Geological Magazine* for January, 1903, p. 28. He names it *Homalonotus Barratti, sp. nov.* He also describes in the same paper a fragment of a smaller trilobite—*Phacops latifrons* (?)—from the mainland opposite Trescore Island, also found by Mr. Barratt.

Through the kindness of Dr. Woodward I am able to present to your Museum wax models of these specimens, the fossils themselves being in the British Museum, South Kensington. The annexed figure of *Homalonotus Barratti*, two-thirds natural size, is from the block cut for the *Geological*

Magazine, which Dr. H. Woodward has most kindly lent to your Society.



Homalonotus Barratti, sp. nov. (H. Woodward).

I am also able to present to your Museum a small slab from Mother Ivey's Bay containing some pyritised organisms which the scour of the sand has brought to light since my former visit. Mr. R. Buller Newton, of the British Museum, was good enough to examine them, and he reports as follows :—

"The smallest organism in this slab is a Brachiopod shell, which appears to be a form allied to *Retzia longirostris*, Kayser (= *Terebratula ferita*, Schnur non Von Buch). The perforations of the shell-structure are remarkably well seen in this specimen, together with the concentric ornamentation between the few and prominent costæ

which characterise this species. A distinct median septum is also present."

On the same slab occur the remains of an *Orthoceras* resembling *O. gracile* (Blumenbach).

Mr. Newton refers to some small slabs from Booby's Bay as follows:—

"One of the small slabs contains a group of Gastropods resembling *Euomphalus serpens* (Phillips), as figured in 'Figures and Descriptions Palæozoic Foss., Cornwall,' etc., 1841, vol. xxxvi., Fig. 172, but being casts, no ornamental striations are observable. The most prolific fossil in these states is a minute form of *Tentaculites*, which is apparently smooth or only very delicately annulated, and which is possibly allied to *T. lævis* of Richter (*Zeitsch. Deutsch Geol. Ges.*, 1854, vol. vi., p. 284), found in the Lower Devonian beds of Thuringia. I am glad to be able to confirm your determination of the small bivalve in a piece of slate. I think there is no doubt that this specimen is *Cardiola retrostriata*, as I can see very obscure indications of the characteristic transverse ridging in the costæ."

In the summary of the above paper, read to you three years ago, I mentioned that "*Pleurodictyum* does not appear north of Porthcothan nor south of Bedruthan." I am glad of this opportunity to correct this statement. My friend, Mr. Walter Barratt, has since found it as far south as Step Cove, immediately north of Watergate Bay, and I

have found it in some abundance as far north as Booby's Bay, so that it can in no wise be considered a zonal fossil in this district.

It is a matter for great congratulation to all Cornishmen that the Geological Survey Department has at last undertaken the thorough survey of their county. This district has been under the personal superintendence of Mr. Clement Reid, F.R.S., so that we may expect shortly to have the pleasure of seeing his report, and noting considerable additions to our recorded fossils.

The fossils mentioned in Table No. 2, pp. 542–5 of your current vol. xii., as found by myself and identified by the leading experts therein mentioned, have all been deposited either in the British Museum or in your own Museum.

CORNISH RADIOLARIAN CHERTS.

In addition to the exposures of these rocks, recorded in your *Transactions* and elsewhere,[1] there is a grand section opened on the London and South Western Railway immediately east of Egloskerry station.

The railroad has been cut through the base of a spur of the high land called Red Moor, and as passengers travel from Launceston they will see on the south side of the line as they approach Egloskerry, a wall some fifty feet high, composed

[1] *Trans. Royal Geol. Soc. Cornwall*, vol. xii. part i., 1896, pp. 39–70; vol. xii. part iv., 1899, pp. 278–81. *Trans. Devon. Assoc.*, 1896, vol. xxviii. pp. 774–89. *Quart. Journ. Geol. Soc.*, vol. 51, 1895, pp. 609–98.

of beds of radiolarian rocks varying from half an inch to eighteen inches in thickness. The rock may be described as chert, passing into shale, and is mostly of a dark colour. The beds have a westerly dip. A quarry has been opened in these beds about 900 yards S.S.E. of Egloskerry Church. The railroad is ballasted, and the public roads are metalled with this rock.

The extensive high land of Red Moor, 631 feet above sea-level, like many of the hills to the eastward of this district, appears to owe its existence to the erosion of radiolarian cherts being effected at a slower rate than that of the other sedimentary rocks in this region.

ON A LENTICULAR VEIN OR ENCLOSURE OF "SUGARY QUARTZ" IN HORNBLENDE SCHIST.

The specimen of "Sugary Quartz" which I place in your Museum comes from a lenticular vein or enclosure in a quarry lately opened in the Hornblende Schist Cliff half a mile north of Porthoustock by the St. Keverne Stone Co. The quarry foreman states that it was eighteen inches thick in one part, and fined away to nothing. I sent a specimen and photographs, with a coloured sketch by Mr. Samuel Roberts, of the present exposure of this and some smaller veins above it, to Dr. Flett, of the Geological Survey, who had the rock sliced for microscopic examination, and reported as follows:—

"SLIDE E, 3894.

"A mosaic of small grains of crystalline quartz, irregular in shape, mostly angular, averaging about ·25 mm. in diameter. They do not appear to have been crushed, and show no cataclastic structures. Very minute fluid cavities are the only enclosures. The mineral is remarkably pure, though stained in the hand specimen with ferruginous incrustations."

Dr. Flett further writes:—

"From looking at your photographs I am inclined to think that the quartz you sent up is from a vein which has formed alongside of the master joints of the Hornblende Schist parallel to the bedding. Under the microscope it is not like a quartzite, and such quartz veins are common in Hornblende Schists which have been much folded (*e.g.* in the Scottish Highlands), though, of course, less frequent than in rocks of more acid composition."

There were large blocks of calcite also lying about the quarry, which the foreman said came from a large run lower down and further south in the quarry; but this was covered with rubbish during my visits, so I could not see it. The quarrymen have christened the quarry "Ballarat." The "sugary quartz" is near the top of the north end of the quarry, which is about one hundred yards south of Porthkerris Cove beach.

GUNWALLOE.

Since the paper on Gunwalloe appeared in your *Transactions*[1] there has been no determinable fossil discovered there. A fragment now presented to your Museum was referred to Dr. Hinde, F.R.S., who writes:—

"The piece on which you have marked 'distinct structure' has somewhat the appearance of a small tabulate coral, but I could not definitely say that it was an organism of this character."

The Plate 17 in the above volume of your *Transactions*, giving a sketch of an organism from Gunwalloe fishing cove, should have had a note of interrogation after the suggested name of "*Nematophycus, Hicksii*" (?).

[NOTE.—Since this paper was in the press heavy seas exposed some fossiliferous rocks which are seldom visible. I sent some specimens of the black markings to Dr. A. Smith Woodward, F.R.S. He writes: "I think most, if not all, of them are fish remains; but they are much too fragmentary to be named."]

[1] Vol. xii., 1901, pp. 434-7.

A TRACHYTIC BOULDER.

By Richard Pearce.

I have brought with me from Colorado a specimen of Trachytic Boulder, coated with a mineral rich in gold and silver, associated with other metals—lead, copper, and antimony, combined with sulphur.

The specimen is from the "Bassick" Mine, Colorado, which was extensively worked some twenty years ago for the precious metals.

The deposit is a peculiar one from a geological point of view, and has been pronounced by well-known geologists as being of geyser origin. It has been worked to a depth of some 900 feet, having a width (or diameter) of from 20 to 100 feet.

An interesting feature is the occurrence of wood charcoal in the ore down to the depth of 800 feet.

A series of specimens illustrating the character of the deposit, together with a specimen of the charcoal, may be seen in the Museum of Practical Geology at Jermyn Street, London.

These specimens were presented by myself some twenty years ago, and are well worth a careful study by those who are especially interested in the genesis of mineral deposits. It may be interesting to state that the pores of the charcoal are lined with most beautiful transparent crystals (microscopic) of quartz having double terminations (double six-sided pyramids).

A PLEA FOR THE STUDY OF CORNISH QUATERNARY GEOLOGY.

By Rev. D. Gath Whitley.

I am aware that the term Quaternary, as applied to a geological epoch, is not entirely satisfactory. It is declared that the superficial deposits included under this word are insignificant in extent and in depth. It is further maintained that the Quaternary beds have no characteristic fauna or flora, such as we find in the Primary, Secondary, and Tertiary Periods. And it is also stated that it is difficult, and often impossible, to draw a hard and fast line to mark the place in the geological record where the Tertiary formations end and those of the so-called Quaternary Period begin.

I am not disposed to undervalue these objections, but I cannot consider them to be conclusive. In Great Britain our superficial Quaternary deposits are by no means unimportant, and when we realise the enormous development of Post-Tertiary sands, clays, and gravels in Northern and Eastern Europe, we perceive that their extent furnishes a good reason for classifying them as meriting a particular geological nomenclature. So far as palæontology is concerned, I also consider that the term Quater-

nary is well merited. The mammalian fauna of the superficial clays and gravels, with its elephants, lions, hyænas, rhinoceroses, and hippopotamuses in Europe, its huge sloths in America, and its equally gigantic marsupials in Australia, presents a characteristic feature which everywhere marks out the Quaternary beds as belonging to a special epoch.[1]

There is, however, another particular argument in favour of this view, which may be stated as follows. Each of the great divisions in the Geological Record is characterised by the predominance of a certain type of animal life, which gives to the epoch its particular character. Thus the Primary Era is marked by a predominance of *fishes*, which being the prevailing organism in the epoch,[2] have caused it to be called "The Age of Fishes." In like manner, in the Secondary Period, the most important creatures are the *reptiles*, so that the epoch is popularly termed "The Age of Reptiles." In the Tertiary Era, also, the leading animal type which prevails over all others is that of the *mammalia*, which has led, very properly, to the era being known as "The Age of Mammals."[3] So

[1] This argument is well developed by M. D'Archiac in his valuable work entitled *Faune Quaternaire.*

[2] I do not consider that the existence of some small and low forms of reptiles in the Carboniferous and Permian deposits invalidates this conclusion.

[3] Of course I attach due importance to the fish of later periods and to the reptiles of the Palæozoic and Kainozoic Eras, as well as to the small Secondary mammalia. I merely give the *popular* phraseology, which is based on the *preponderance* of the type at the eras I have mentioned.

it is with the Quaternary Period. The creature which at that time specially prevailed, and which gave a particular character to the epoch, was *Man.* The Quaternary Era is the "Age of Man." Here we find his bones, weapons, and various implements, and when we consider the amazing influence which Man exercises on Nature, in subduing its creatures, in modifying its aspects, in discovering its secrets, and in interpreting its laws, we realise how completely the epoch in which he manifests his presence is separated from those which preceded it. It is the *Anthropological* argument, therefore, which leads me to decide that the term Quaternary, as signifying a special geological period, is well chosen and perfectly justifiable.

In making this statement, it will be observed that I reject the opinion that Man lived in the Tertiary Era. The so-called cut bones, human relics, and diminutive flints, found in the Pliocene and Miocene deposits do not seem to me to warrant this conclusion. They cannot be proved to be the work of Man, and seem probably to be merely natural fragments, or the results of the works of animals on land or sea. This is the opinion of our leading English geologists,[1] and many of the chief scientists on the Continent hold the same view.

I understand, then, by Quaternary deposits all

[1] This is the opinion of Sir John Evans in his *Ancient Stone Implements of Great Britain* (second edition), p. 658, and *Address to the British Association at Toronto in 1897*, pp. 8, 9. Professor Boyd Dawkins expresses the same opinion in *Early Man in Britain*, pp. 66, 90.

those sands, clays, and gravels which lie between the latest Pliocene formations and the present day, and I also include in it those recent alluvial deposits which are forming under our eyes to-day. The attempt to draw a distinction between the Quaternary and the recent eras is, in my opinion, quite needless.

Now in Cornwall we have an interesting series of these deposits, and one which can be very easily studied. The excellent arrangement given by Mr. W. A. Ussher[1] is so useful that I shall generally follow it, although a chronological chart of these beds can hardly be made in a satisfactory manner.

More than sixty years ago Sir Henry De la Beche described certain aberrant beds of clay and gravel in Cornwall, which he looked upon as the oldest of our superficial deposits.[2] These were the clays of St. Agnes Beacon and the quartz gravels of Crowsa Downs. Mr. Ussher fully agrees with this opinion as to the age of these beds, considering them to be Pre-Glacial. Into this controversy, which touches the way in which these beds were formed, I do not enter; I merely look upon them as early Quaternary and of Palæolithic age.

Those extensive beds of Stream-Tin, which were formerly so profitably worked in Cornwall, must

[1] *Post-Tertiary Geology of Cornwall.* See table at the end of the work.

[2] *Report on the Geology of Cornwall, Devon, and West Somerset,* pp. 395, 396.

also be considered as Quaternary. Into the controversy relating to their origin I do not enter, but it is singular to notice that the old opinions on this point have recently been revived. In his classical essay on the Cornish Stream-Tin beds, published in the *Transactions* of this Society,[1] Mr. Joseph Carne maintained that these deposits were formed by a great flood, and this view was accepted by Sir Henry De la Beche.[2] In the present day this theory of the diluvial origin of our Stream-Tin beds has been accepted by Sir Joseph Prestwich[3] and Sir Henry Howorth.[4]

Next come our "Raised Beaches," which are so numerous around our coasts. Their difficulties are not yet all unravelled, but no one can look on the specimens which are presented in Gerrans Bay and at St. Ives and Godrevy without realising the necessity of accurately examining and classifying them.

Over the Raised Beaches lies that peculiar deposit which deserves the closest investigation, and is called "The Head of Rubble," or, more briefly, "The Head." This has been well described by Sir Henry De la Beche as a mass of earthy detritus full of angular fragments.[5] It is more

[1] *Trans. Royal Geol. Soc. Cornwall*, vol. iv. pp. 55, 56.

[2] *Report on the Geology of Cornwall, Devon, and West Somerset*, pp. 410, 415, 416.

[3] *Quart. Journ. Geol. Soc.*, vol. xlviii., 1892, p. 316.

[4] *Geological Magazine*, vol. ix., 1882, pp. 517, 518.

[5] *Report on the Geology of Cornwall, Devon, and West Somerset*, p. 432.

than a mere rubble formed by the decay of the subjacent rocks, and frequently shows itself as a mass of earthy materials, which has been evidently formed by aqueous transport. It varies in colour texture, thickness, and composition in different localities. It frequently is from twenty to thirty feet thick in Gerrans Bay, and in other places this thickness is often exceeded. This deposit does not seem to me to have received the attention that its importance deserves, although Sir Joseph Prestwich has described it at great length.[1] The "Head" is considered to be the latest of Quaternary deposits, which are of Palæolithic age.

To these beds succeed our Submarine Forests and many stretches of blown sand, the beds of alluvial detritus now forming, and the "Overburden" lying over the Stream-Tin grounds. I need not allude to these formations any further.

Now all these deposits seem to me to be much neglected. I rarely hear them described in papers at meetings, and they seem to be left out in discussions. Frequent references are made—most properly—to our solid rocks, to their position, classification, and organic remains. Our granites and elvans constantly receive attention, and the literature relating to our serpentines is of a voluminous character. Chemical geology, with its formidable tables of quantitive analysis, is ever present, and the microscopic examination of our rocks is frequently presented. But I fail to see

[1] *Quart. Journ. Geol. Soc.*, vol. xlviii., 1892, pp. 286, 290.

the same energy bestowed upon the examination of our numerous Quaternary deposits.

Why is this, surely not because the study is uninteresting? To the geologist ***no branch*** of his science is without its special interest and value. Will it be said that our Quaternary beds are unimportant in extent and in thickness? I cannot for a moment agree with the objection.

In Gerrans Bay the Head of Rubble extends along the coast from Porth Bay to the Nare Head, a distance of ten miles, and in some places it is thirty feet thick. Equally interesting is its development in the neighbourhood of Falmouth, from Pendennis Castle to Maen Porth. In Mount's Bay, between Newlyn and Mousehole, the Head is forty feet thick, and Mr. W. J. Henwood estimated the combined thickness of the Stream-Tin beds and the Overburden at one spot in the Luxulyan Valley at no less than fifty feet.[1] It is impossible to consider such formations unimportant. The *Transactions* of this Society bear witness to the care bestowed in examining and describing our Cornish superficial deposits by those who bore the honoured names of Boase, Carne, and Henwood, and by our honoured President, and these beds formed the special subject of study of one who devoted the best years of his life to the elucidation of the problems of Cornish geology, and whom I am proud to call my Father.

Apart from the general interest of the question,

[1] *Trans. Royal Geol. Soc. Cornwall*, vol. iv. pp. 61, 63, 64.

I plead for a study of these beds for three specia reasons.

First, because this study will throw light on th problem of the Antiquity of Man in Cornwall. I Devonshire the bones and implements of Man which have been found in Kent's Cavern and i the cave at Cattedown, have proved the presenc of Palæolithic Man in the neighbouring county Such relics have not been found in Cornwall Of course, everyone is acquainted with the larg numbers of shattered flints and flint nodules an pebbles which occur on the surface and in th subsoil of our county. But their age is doubtful and their origin uncertain. Nevertheless, the searc should go on, and the form, size, and position o such flints when found should be carefully noted The Raised Beaches should be particularly exam ined; I myself have not yet found flints in them The Head of Rubble, lying over our Raise Beaches, is, I think, the most likely place fo finding artificially formed flints of Palæolithic age Near Porthscatho, at Godrevy, and in the neigh bourhood of Falmouth, large earthy masses of th Head are continually falling from the face of th cliff on to the beach below. Thus new sections o considerable size are being constantly laid bare, an there is from this cause a good chance of findin large flints, either in the newly exposed face of th cliffs or on the beach below.

Near Brighton, not long ago, a large flint im plement was found in the Head, and a simila

discovery might be made at any time in our own earthy cliffs. Let local geologists be on the look out, for such finds would be most important. Large flints have been found in our Stream-Tin deposits, but I have not had the good fortune to examine any of them. I have been told that their numbers were great, and their occurrence in a Palæolithic deposit is a fact of very great importance.[1]

Secondly, the study of our Quaternary beds may reveal the existence of the great Palæolithic mammalia in Cornwall. In the limestone fissures at Plymouth, and in the lower beds of Kent's Hole and of Brixham Cavern, as well as in the Cattedown fissure, the bones of the lion, hyæna, elephant, rhinoceros, and hippopotamus have been found in great abundance. But no remains of these great beasts have, as far as I know, been as yet discovered in Cornwall. This seems strange, although reasons may be advanced to account for their not having been found. It may be that they originally lay so near the surface that the scanty covering of rubble and clay which overspread was not deep enough to preserve them from the action of the disintegrating agencies of the atmosphere, which prevailed very powerfully during the Neolithic Period. It seems to me that some of the legends of the giants in Cornwall may perhaps owe their existence to the finding of some of the bones of the great Palæolithic mammalia in prehistoric times. The

[1] The discoveries of flints in Stream-Tin, to which I allude, occurred in the Luxulyan Valley.

Head of Rubble, with its earthy masses of various texture and chemical composition, seems the best deposit in which to search for these bones, especially when we remember that large earthy masses of the Head are constantly falling on our beaches and exposing new sections. On the shores of the Arctic Ocean, in Siberia, the low earthy cliffs are frozen hard and are full of mammoths' bones. When an unusually warm summer occurs the frozen gravel and earth are thawed, so that large masses of earth fall on the beach.[1] Then the bones of these great elephants appear sticking out of the cliffs, or are seen lying on the beach.[1] Why should not the same sights be seen in Cornwall, owing to the disintegration of the Head of Rubble? It must also be remembered that in the "Overburden," which has been found overlying many of our Stream-Tin deposits, the bones of many deer and wild oxen have been discovered,[2] particularly at Carnon and Pentewan. Why should not similar, or different, bones be found in our earthy deposits of an earlier age and of a different character?

Thirdly, the Quaternary deposits of Cornwall may furnish us with information concerning the nature of the passage from the Palæolithic to the Neolithic Period. Two theories are held with reference to this transition. One is that the passage extended over a long period of time and was of a tranquil character. The other is that the change

[1] *Siberia and the Polar Sea*, by Admiral Wrangell, pp. 215–17.
[2] *Trans. Royal Geol. Soc. Cornwall*, vol. vii. pp. 265–7.

from the Earlier to the Later Stone Age was short and very violent, and that it was accompanied by a tremendous invasion of tumultuous waters, or, as it is often called, a great diluvial catastrophe. According to some geologists, this cataclysm rapidly deposited our Stream-Tin beds and the Head of Rubble, and many French geologists maintain that this aqueous *débâcle* formed the extensive Quaternary beds of clay, sand, and gravel, which in France are still called *Diluvium*.[1] I do not enter into this controversy, in which, in the words of Sir Roger de Coverley, "there is much to be said on both sides." Still I believe that the great dimensions which the Head of Rubble attains in our cliffs will afford good opportunities for investigating the subject.

I consider that in theorising on the origin of our Cornish superficial deposits much light may be gained from the study of the very extensive series of Quaternary beds in Northern France, Belgium, and Holland. To take one instance only. The strange deposits of clay and sand on St. Agnes' Beacon have much perplexed Cornish geologists, and many different theories have been put forward to explain their origin. I do not discuss them, but ask that they may be studied in the *Transactions* of this Society, from the time when they were put forward by Messrs. Hawkins and Boase[2] down to

[1] I allude particularly to the works of MM. Tardy, Belgrand, and d'Acy, who, in describing the Quaternary deposits in France known as the *Diluvium Gris* and *Diluvium Rouge*, are of opinion that these beds were formed by a great flood.

[2] *Trans. Royal Geol. Soc. Cornwall*, vol. iv.

the recent examination of these deposits by Messrs. Kitto and Davies.[1] I would, however, call attention to the fact that precisely similar beds of sand and clay of Quaternary age are found in Northern France and Belgium. They occur at elevations about the same as the St. Agnes beds, and occupy the tops of hills, and cross the summits of watersheds.[2] The study of these superficial deposits is as interesting as it is important, as in this portion of Europe the Quaternary beds are developed on a grand scale.

For these reasons, and for others which I need not dwell upon, I plead for a close and a continuous study of our Cornish Quaternary deposits. After the admirable lead given to us by Mr. Ussher, we ought to prosecute the study with the utmost diligence. We must recollect how, in the early days of this Society, this examination was conducted by its leading members, whose writings are enshrined in this library, and of whom it may be said, "If you would see their memorials, look around you."

I learn with pleasure that our Quaternary beds are receiving the greatest attention from the members of the Geological Survey, and I venture to hope that before long their efforts, and those of other labourers in the same field, will lead to discoveries of the utmost importance.

[1] *Trans. Royal Geol. Soc. Cornwall*, vol. ix.

[2] These beds are described in the most valuable work of M. E. d'Acy, entitled *Le Limon des Plateaux du Nord de la France, et les silex travaillés qu'il renferme.* 1878.

A CROSS-SECTION AND SOME NOTES ON THE TIN AND COPPER DEPOSITS OF CAMBORNE,

WITH SPECIAL REFERENCE TO THE LIMITS OF PRODUCTIVE ORE GROUND.

By Donald A. MacAlister, A.R.S.M.

(By permission of the Director of H.M. Geological Survey.)

Cross-sectional drawings have appeared from time to time in Cornish scientific publications, showing the relative positions of the ore-bearing fissures in the Camborne district. Among the most noteworthy are those north-and-south sections of the country comprised between the Basset mines and Wheal Tolgus.[1]

As great, if not greater, riches have been extracted from a section of ground west of that described and figured by Captain Maynard, namely, that which is in the vicinity of the Great Cross Course, which dislocates the lodes common to Cook's Kitchen and Dolcoath mines, by a horizontal distance of seventy-four fathoms.

[1] J. Maynard: "Remarks on two Cross-sections through Carn Brea Hill and the Neighbouring Mines," *Forty-First Rep. Royal Corn. Poly. Soc.*, p. 190; "Notes on a Cross-section from Cook's Kitchen to Wheal Emily Henrietta," *Rep. Miners' Assoc. Corn. and Devon*, p. 65.

The diagrammatic cross-section[1] of Dolcoath is so well known that, in making a cross-sectional drawing of the lodes on the west of the Great Cross Course, it is better to omit Dolcoath and to insert, instead, the extension of its lodes westward in the Carn Camborne and Camborne Vean mine setts. The appended section is compiled from old cross-sectional drawings of the mines located on the Tehidy and Pendarves estates, but would be incomplete without some diagrammatic conjecture, and it is hoped it will supplement the work of others (Fig. 1).

Remarks on the Cross-section.—The subterranean ridge of granite seen in Camborne Vean mine is also found in Dolcoath, South Crofty, East Pool, and, presumably, Wheal Tehidy, along a line bearing approximately E. 30° N. In nearly all its course the hollow between the ridge and the main mass is associated with parallel elvan dykes or lodes. In South Crofty the granite on the north wall of Pryce's lode is ten fathoms higher up than on the south, and in the Camborne Vean lode the difference is between ten and twenty fathoms. It is probable, therefore, that the granite is faulted down on the south along this feature.[2]

[1] By Mr. Phillips, late surveyor of Dolcoath. See also "Notes on the Great Main Lode of Dolcoath, Cook's Kitchen, Tincroft, and Carn Brea Mines," by R. J. Frecheville, *Trans. Roy. Geol. Soc. Corn.*, vol. x. p. 146.

[2] That some of the lodes on the south of the Carn Brea Hill fault the granite is well known.

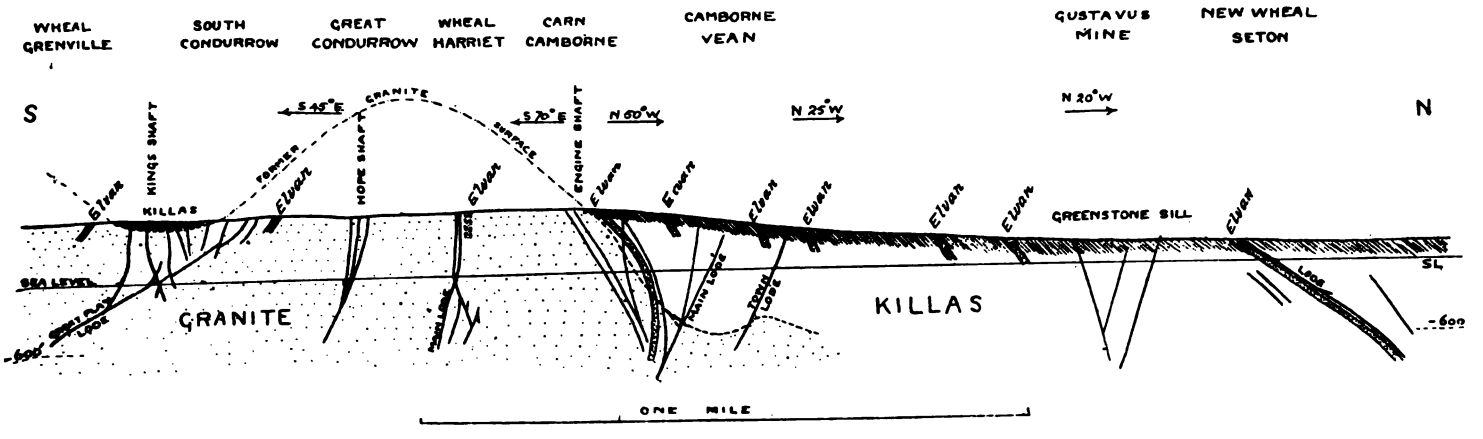


FIG. 1.

CROSS-SECTION OF THE CAMBORNE LODES ON THE WEST OF THE GREAT CROSS COURSE.

The lodes shown in the cross-section may, as far as they have been explored, be divided into two groups; those in the killas, on the north of the section, have produced mainly copper, while those in the granite mainly tin; but they are all tin-copper lodes.[1]

The lodes in this district appear to be influenced in the direction of their underlie by the elvans,[2] while it is interesting to note the remarkable change in the direction of underlie of the latter in glancing from one end of the section to the other.[3] It has already been pointed out that "Granite, or its modification, elvan, occurs at or near all the localities where tin and copper ores so abound."[4] We may therefore say that in the Camborne area the lodes are ore-bearing fissures in the vicinity of elvan dykes;[5] from this point of view the ores must

[1] Wheal Seton alone, between the years 1847 and 1872, produced £350,000 by sale of its ores, mainly copper. Great Condurrow, from 1844 to 1873, about £484,000 of copper and tin ores. South Condurrow, from 1864 to 1895, about £590,000 of tin ore and some copper. (Information kindly supplied by Mr. Vercoe, of Pendarves Estate Office.)

[2] Robert Were Fox: "On Mineral Veins," *Rep. Corn. Poly. Soc. Falmouth*, 1836, p. 96.

[3] De la Beche has already called attention to the apparent convergence of elvans in depth, as if derived from the same source (*Geol. Rep. Cornwall, Devon, and W. Somerset*, p. 176). Some of the jointing in the granite appears to be subsequent to the intrusion of the elvans, but proof is as yet wanting. See *Trans. Roy. Geol. Soc. Corn.*, 1901, vol. xii. part vii. p. 553.

[4] De la Beche: *Geol. Rep. Cornwall, Devon, and W. Somerset*, p. 286.

[5] See "Plutonic and other Intrusive Rocks of West Cornwall in their Relation to the Mineral Ores," by Mr. J. B. Hill, R.N., *Trans. Roy. Geol. Soc. Corn.*, vol. xii. p. 588. Mr. Hill speaks of the co-

be regarded as having been a later product of the same magma which gave rise to the elvans.

General Geological Peculiarities of Camborne.—The main facts, so well known, may be epitomised as follows :—

The Palæozoic sediments and the intrusive sheets of greenstone were disturbed and metamorphosed in post-carboniferous times by granite,[1] which has also penetrated the killas as sheet-like intrusions.[2] It is certain that a great mass of sediment must have covered all the granite bosses now visible at the surface.[3] Shortly after the consolidation of the peripheral granite, the elvan dykes were injected from the same eruptive centre along planes of fracture, having a general bearing E. 30° N., and traverse both killas and granite alike. Then followed the period during which lodes were formed.

incidence of the general bearing of lodes and elvans with that of the tough-way joints in the granite.

[1] Mr. J. B. Hill, of H.M. Geological Survey, has touched on the possible laccolitic nature of the granite. Victoria County History. Cornwall. Geology section.

[2] W. J. Henwood: "The Metalliferous Deposits of Cornwall and Devon," *Trans. Roy. Geol. Soc. Corn.*, 1843, vol. v. p. 58. Sheet-like intrusions, similar to those mentioned by Henwood, were also found at Killivose mine, on the south-west of Camborne.

[3] Estimated by Mr. J. H. Collins at 46,000 feet in thickness ("Geological Age of Central and West Cornwall," *Journ. Royal Inst. of Cornwall*, 1881); and by Sorby ("On the Microscopical Structure of Crystals indicating the Origin of Minerals and Rocks," *Quart. Journ. Geol. Soc.*, 1858, vol. xiv. p. 453) at 50,000 feet for the Carn Menelez granite, or about 9½ miles. The evidence for this very high estimate is, however, not conclusive, but it is sufficient to show that an enormous mass of sediment overlay the granite at one time.

The greenstone is found at the surface in many places, and is the oldest of the igneous rocks.

Mr. Teall[1] has referred to the apparent sequence of eruption from basic to acid rocks.

Finally, cross courses, probably Tertiary, have faulted the district in a N.N.W. direction (Fig. 2).

The Mineral Lodes.—The formation of the lodes was the latest phase of the plutonic activity.[2] They have the same general bearing as the elvans, and are simple or bifurcating altered ore-bearing fissures—frequently fault-planes—in which the tin ore occurs as bunch or pipe-like deposits, due to infilling of the fissure (so forming a leader) and impregnation of country rock in its vicinity.[3]

The pitch of these ore bunches, in accordance with similar observations by Henwood,[4] in other districts appears to be easterly.[5] Sir Clement Le Neve Foster found in Wheal Uny that no part of the lode was absolutely barren, so that the pitch of the bunches could not be determined. I have concluded from consultation of many longitudinal

[1] J. J. H. Teall: "Metamorphism in the Hartz and West of England," *Trans. Roy. Geol. Soc. Corn.*, 1889, vol. xi. p. 221.

[2] De la Beche: *Geol. Rep. Cornwall, Devon, and W. Somerset*, p. 310.

[3] *Ibid.*, p. 317. Clement Le Neve Foster: "The Tin Deposits of East Wheal Lovell," *Trans. Roy. Geol. Soc. Corn.*, 1876, vol. ix. part ii. p. 8; "On the Great Flat Lode," *Quart. Journ. Geol. Soc.*, vol. xxxiv., 1878, p. 640.

[4] *Trans. Roy. Geol. Soc. Corn.*, vol. v. pp. 54, 87, 193.

[5] At Wheal Grenville they are very pronounced, and at Dolcoath the principal ore body is coincident with the line of junction of the bifurcating main lode, and the change in strike of the main lode near the caunter.

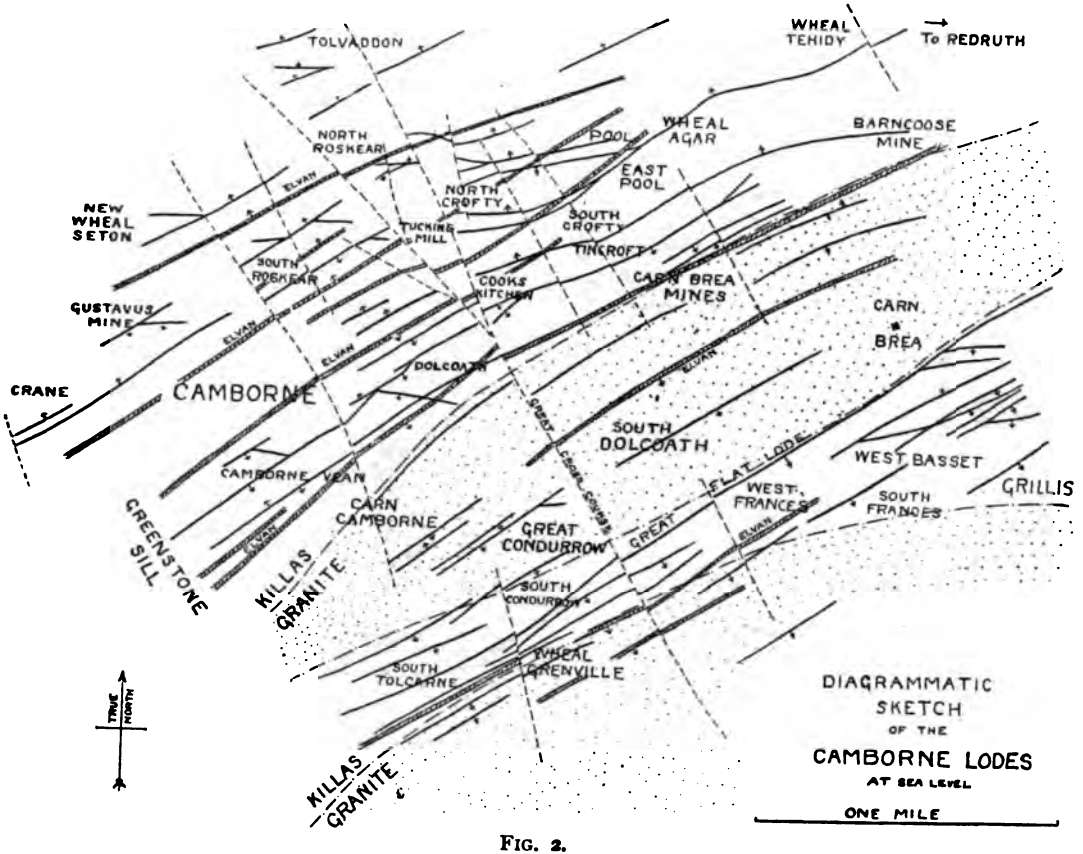

TOLVADDON
WHEAL TEHIDY
To REDRUTH
NORTH ROSKEAR
POOL
WHEAL AGAR
BARNCOOSE MINE
EAST POOL
NEW WHEAL SETON
NORTH CROFTY
SOUTH CROFTY
TUCKING MILL
TINCROFT
SOUTH ROSKEAR
COOKS KITCHEN
CARN BREA MINES
CARN BREA
GUSTAVUS MINE
DOLCOATH
CRANE
CAMBORNE
SOUTH DOLCOATH
WEST BASSET
FLAT LODE
WEST FRANCES
SOUTH FRANCES
GRILLIS
CAMBORNE VEAN
CARN CAMBORNE
GREENSTONE SILL
KILLAS
GRANITE
GREAT CONDURROW
SOUTH CONDURROW
SOUTH TOLCARNE
WHEAL GRENVILLE
TRUE NORTH
DIAGRAMMATIC SKETCH OF THE CAMBORNE LODES AT SEA LEVEL
ONE MILE

FIG. 2.

sections that the copper ore ground has a great tendency to assume a horizontal position along the strike of the lode. Various writers[1] endeavoured to give different ages to the Camborne lodes, but De la Beche assumed rather a certain period during which fissures would be open to fluctuating action.

Caunter Lodes.—In the Camborne district there are at least a dozen caunter lodes, forming a distinct fissure system, having a bearing approximately east and west. It seems that these lodes are really subsidiary fractures contemporaneous with the main lode fissures.[2] Although caunter lodes seem more prominent in the upper workings of mines, and in consequence of that position more often are copper-bearing, they have, nevertheless, their deep-seated tin-bearing representatives.[3] The caunter lodes occur more frequently on the underlie side of the main lodes than in the footwall side. The constant uniform relation of the caunters to the main lodes, with which they are associated, seems to indicate that all these fissures were the results of one general strain[4] (Fig. 3).

[1] J. Carne: *Trans. Roy. Geol. Soc.*, 1822, vol. ii. p. 49.

[2] W. J. Henwood: *Trans. Roy. Geol. Soc. Corn.*, vol. v. pp. 253, 327. See also Warington Smyth's remarks: "Physical Phenomena connected with the Mines of Cornwall and Devon," *Brit. Assoc. Rep.* (Plymouth), 1877, p. 8.

[3] Carn Brea, Wheal Basset, etc. The Dolcoath caunter lode has been intersected in the 220 fathom cross-cut, and Mr. Hosking (Tehidy Office) informs me that it is now a tin-bearing lode of meagre dimensions.

[4] See "The Plutonic and other Intrusive Rocks of West Cornwall," by J. B. Hill, *Trans. Roy. Geol. Soc. Corn.*, vol. xii. part vii., 1901,

Epitome of General Facts, relating to the Mineral Contents, bearing on the subject of this paper.—The copper ores of the ordinary copper-tin lodes occur at a higher horizon in the lode than the tin, hence,

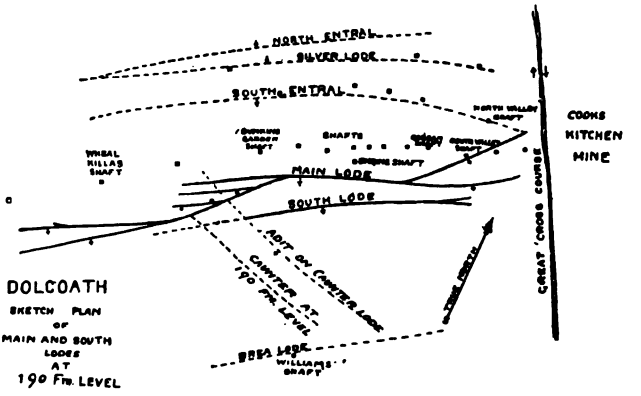


FIG. 3.

in a lode traversing granite and killas the copper is generally more productive in the killas, and the tin in the granite, although neither ore is restricted to those rocks respectively.

When, as sometimes happens, leaders of tin and copper ores occur side by side, the width of the lode is greater than usual.[1]

Gozzans characterise the upper parts of copper lodes, while in tin lodes, found outcropping in bared granite districts, this peculiar feature is less pronounced or entirely lacking.

Tin was, however, extracted by the old miners

p. 551 *et seq.* I am indebted to Mr. H. V. Thomas, of Dolcoath Mine, for his kindness in working out this figure, which shows the relation of the Dolcoath main lode to the caunter.

[1] W. J. Henwood: Address Roy. Inst. Corn., 1871.

from the backs of many gozzans.[1] The tin was probably concentrated by nature in the back of the lode by the leaching out of the unstable copper sulphides by weathering. Below the weathered zone various oxidised copper ores were found, below which came rich sulphides of copper, so much so that proportionately the tin present was reduced in many cases to an insignificant bye-product, while in depth the copper died out, and the lode became a tin one.

Ore Ground.—The "ore ground" is a commercially valuable zone, in which the ore bunches in the lodes contain a payable percentage of tin and copper.

Henwood has already stated that the richest mines are those situated around the granite margins.

It is also well known that many mines were abandoned in depth because they were considered as worked out. In other words, the fissure continues in depth, but is much poorer. Numberless instances are available[2] of this. The richest tin zone in a series of ore fissures bears a fairly definite position with regard to the surface of the granite,

[1] J. H. Collins: "Sketch of the Geology of Central and West Cornwall," *Geol. Assoc.*, 1887, p. 20; "Origin and Development of Ore Deposits in the West of England," *Journ. Roy. Inst. Corn.*, 1892. Many of the lodes in Gwennap district had tin in the backs, while Carn Brea is an example in this district.

[2] Carn Brea, once one of the greatest mines in the country, is a mine still working, but practically exhausted in depth.

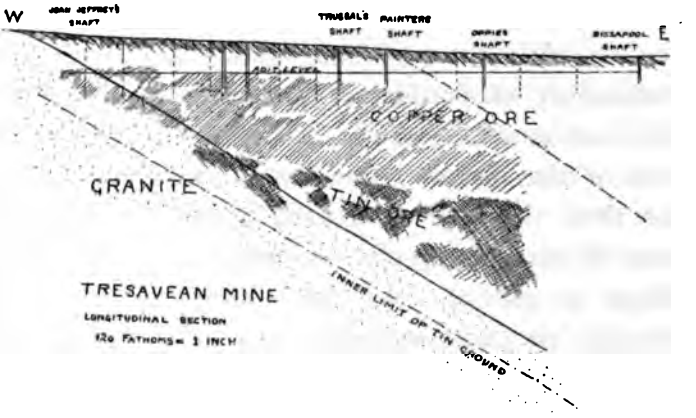

W
JOHN JEFFREY'S SHAFT
TRUSCAL'S SHAFT
PAINTERS SHAFT
ORRIES SHAFT
BISCAWOOL SHAFT
E
COPPER ORE
GRANITE
TIN ORE
TRESAVEAN MINE
LONGITUDINAL SECTION
120 FATHOMS = 1 INCH
INNER LIMIT OF TIN GROUND

FIG. 4.

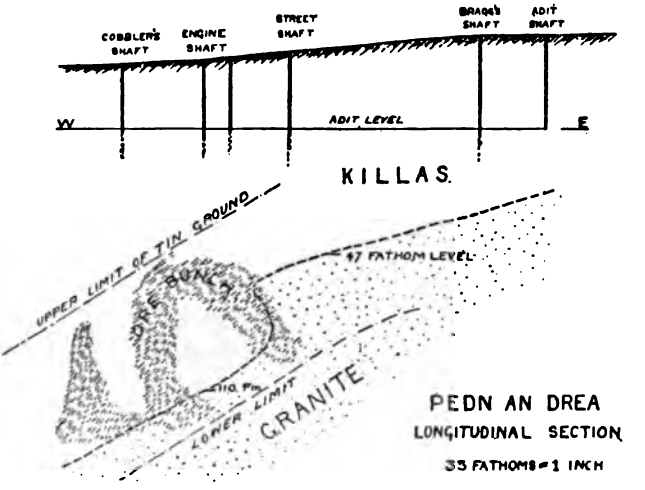

COBBLER'S SHAFT
ENGINE SHAFT
STREET SHAFT
BRAGG'S SHAFT
ADIT SHAFT
W
ADIT LEVEL
E
KILLAS
UPPER LIMIT OF TIN GROUND
37 FATHOM LEVEL
ORE BODY
GRANITE
LOWER LIMIT
PEDN AN DREA
LONGITUDINAL SECTION
33 FATHOMS = 1 INCH

FIG. 5.

i.e. it is generally more or less parallel to it,[1] and bends with it,[2] while its commonly occurring vein accompaniment, tourmaline, behaves similarly. The uncertainty of predicting the depth to which the rich ore ground extends in any district is, in the case of tin, due to ignorance of the conditions at the time the lode was first formed, and, in the case of copper, largely on secondary enrichments (Figs. 4 and 5). In the Camborne lodes the valuable tin zone was deposited at a considerable depth below the original surface. (See footnote 3, page 777.)

Notes and Conclusions.—The question as to the origin of our mineral deposits in Camborne involves references both to primary and secondary enrichments. The literature on the subject is extensive.

The depositions of tin ore in the Cligga Head granite has been ascribed to pneumatolytic action.[3] Le Neve Foster, in a few classic papers, described the processes of deposition which must have gone on in our ordinary lodes.[4]

[1] Tresavean, Levant, Pedn an Drea, West Poldice and Unity Wood, Wheal Edward, etc.

[2] De la Beche: *Geol. Rep. Cornwall, Devon, and W. Somerset*, p. 335. The nature of ore ground is graphically represented in longitudinal sections of lodes, which strike into the granite at right angles to its margin.

[3] Clement Le Neve Foster, F.R.S.: *Trans. Roy. Geol. Soc. Corn.*, vol. ix., 1878, p. 213. Mr. J. B. Scrivenor, M.A. (H.M. Geol. Survey): *Quart. Journ. Geol. Soc.*, vol. lix., 1903.

[4] "Remarks on some Tin Lodes in the St. Agnes District," *Trans. Roy. Geol. Soc. Corn.*, vol. ix. p. 185; "The Tin Deposits of East Wheal Lovell," *id.*, vol. ix. part ii. p. 8, 1876; "On the Great Flat Lode," etc., *Quart. Journ. Geol. Soc.*, vol. xxxiv., 1878, p. 640.

Primary Impregnation.—The elvan dykes were injected through planes of weakness in the solid peripheral granite, probably from a magma within which was still viscous. At a later date those fractures connected with elvans were more likely to have penetrated to great depths than those found away from elvans. Hence, after the consolidation of the granite, but closely following on the injection of the elvans,[1] they must have drawn freely upon the sources of tin and copper,[2] whereas the fissures and joint planes distant from elvans were not so easily, if at all, accessible to the metal-bearing solutions. Yet some veins have manifestly been open to action for longer periods than others, as the wide-banded "leaders," great thicknesses of "capels," or the lode breccias cemented by tin stone, peach, or quartz often testify.[3] Metalliferous solutions from the interior of the granite mass[4]

[1] Near Gwinnear mineralisation is closely associated with the later of two sets of elvans. E. Dixon, *Summ. Prog. Geol. Survey*, 1901, p. 25.

[2] See also the remarks of Mr. G. W. Lamplugh (H.M. Geol. Survey) in "Economic Geology of the Isle of Man," *Memoirs of the Geol. Survey of United Kingdom*, p. 489.

[3] De la Beche: *Geol. Rep. Cornwall, Devon, and W. Somerset*, p. 339 *et seq.* See contribution by Dr. J. S. Flett (H.M. Geol. Survey): *Summ. Prog. Geol. Survey*, 1902, p. 158.

[4] Professor J. H. L. Vogt: "Cassiterite Veins are genetically independent of the immediate adjacent country Rock," *Problems in the Geology of Ore Deposits.*

Mr. J. B. Hill states that the ores were possibly derived from the lower part of the granite itself ("Plutonic and other Intrusive Rocks of West Cornwall in their Relation to the Mineral Ores," *Trans. Roy. Geol. Soc. Corn.*, vol. xii. part vii., 1901, p. 594).

Mr. J. B. Scrivenor says: ". . . all wholly blue tourmaline in granite modification has either been derived from orthoclase, or crystallised in its present state directly from the magma, whether fluid or vaporous" (*Quart. Journ. Geol. Soc.*, vol. lix., 1903, p. 152).

passed out through fissures towards its periphery, and impregnated the fissures mainly at some certain zone either in the granite or the killas,[1] according to thermal or other physical conditions.

The case of the Great Flat lode, with its exceptionally long "pipes" of tin ore, is an example of prolonged infilling, due, possibly, to association with elvan, and also to the fact that, on account of its flatness, a great deal of this fissure was lying in the critical zone during the formation of the lode. It has been described as a "contact deposit," but strictly speaking it is not so, for this implies "segregation" from the magma; in fact, it is only at the junction of the granite and killas in a very few places. In Wheal Uny, for instance, the lode in killas is at least ten fathoms away from the granite in some places, while in others it is wholly in granite (Fig. 1).

The question now arises as to what is the lower limit of the rich ore ground. The precise boundaries of this cannot be defined, since they are dependent on uncertain factors; but experience has shown that the lodes of this district are not uniformly productive to the deepest points reached by mining, and although the rich ore zone in the Camborne lodes is of great depth,[2] it is to be concluded that further exploration at deeper levels will not provide so extensive a field for mining operations as was met with in the upper levels. The

[1] West Kitty, Wheal Kitty, Polberro, Wheal Vor, etc.

[2] Dolcoath is now over 510 fathoms below surface, the deepest workings being 300 fathoms in the granite. There are several elvan dykes in the sett.

change in the character of the ore from being coarsely crystalline in the upper levels to fine and compact in depth probably accompanies other changes in the lode. It is by no means suggested that the lodes become altogether barren, or that they lose their peculiarities as cassiterite veins; the occurrence of rich ore bodies in depth is not precluded. The works of Vogt and Lindgren[1] do not support any hypothesis which might suggest the total disappearance of the ore in the deeper parts of the lodes. It can only be inferred, then, that, generally speaking, the conditions assisting the deposition of cassiterite from its solutions were more favourable near the periphery of the granite than those nearer their source, and that solutions reaching the cooler regions near the contact deposited the whole of that cassiterite which they had managed to retain in the upward journey.

Allusion has already been made to the fact mentioned by Henwood that the rich mines are situated on the granite margins. There are two important points accounting for this peculiarity: one is that veins near the granite boss are more productive than those situated distant from it; the other is that denudation has resulted in the removal, not only of the superincumbent Palæozoic sediment, but also of a great part of the top of the granite boss, and with them a considerable portion of the

[1] *Trans. Amer. Inst. Min. Eng.*, vol. xxiv.: J. H. L. Vogt, "Problems in the Geology of Ore Deposits," p. 671. Waldemar Lindgren, "Metasomatic Processes in Fissure Veins," p. 520.

most productive parts of the ore fissures, t lowering the surface to the relatively deeper tions of the lodes (Fig. 1).

Various writers have assigned different times the arrival of the tin and the copper in the lo Mr. Hill[1] concludes, however, that the ores of "approximately identical age."

If we suppose that the copper arrived after tin ore, we are faced with two difficulties. O the tin ground has been fairly opened up, we little or no copper in the lode; yet we ought find it at least as a common vein constituent depth. It is also impossible to conceive how great quantities of copper ore, found in the up parts of lodes, could have passed upwards thro the usually compact tin lodes. The evidence later age afforded by the discovery of copper pyr moulded on idiomorphic cassiterite, is insuffici and may refer to a secondary deposition.[2]

Probably, therefore, the copper arrived eit before the tin or at the same time; but all lodes are tin-copper, and belong to one system fracture, so that there seems to be no reason not assuming that differentiation took place (fror common, probably alkaline, solution), whereby cassiterite was concentrated mainly in one pla while the more soluble copper mounted to grea

[1] J. B. Hill, R.N. (H.M. Geol. Survey): *Trans. Roy. Geol. Corn.*, vol. xii. part vii., 1901, p. 593.

[2] See De la Beche: *Geol. Rep. Cornwall, Devon, and W. Some* chap. xii.

heights and was not so restricted in its occurrence.[1]

In the Camborne district it would be difficult to dissociate from the same origin the ores of arsenic, zinc, lead, and silver.

The character of the lode fissures below the rich ore zone is a question not easily answered. In the bottom of deep tin mines, where the tin lode is impoverished, it seems to be mainly a hard, "dry" peach or quartz-tourmaline veinstone, frequently showing the banded form of lodes produced by successive actions, or else a small fissure,[2] the walls of which are altered. Occasionally similar lodes are seen in the denuded granite boss.

In the last part of this paper allusion is made to the varying power of resistance of granite to the action of waters (see p. 792). The unequal weathering of granite exposed to atmospheric agencies proves that the various parts of the mass differ considerably in durability, whatever the cause may be; but the mere fact of the occurrence of fissures in the granite containing minerals concentrated by pneumatolytic actions of varying kinds and under varying conditions is enough to account for the occurrence of granite of uneven durability. Le Neve Foster[3] has de-

[1] Professor Vogt's "Cassiterite Veins," including primary copper. Arsenic may be included.

[2] See also J. E. Spurr: "The Ore Deposits of Monte Christo, Washington," *Twenty-Second Annual Rep. Geol. Survey of U. States*, p. 813.

[3] "The Tin Deposits of East Wheal Lovell." See also *Geol. Rep. Cornwall, Devon, and W. Somerset*, De la Beche, p. 317. See also "Some Principles Controlling Deposition of Ores," C. R. Van Hise, vols. xxiii. and xxiv., *Amer. Inst. Min. Eng. Transactions*, p. 421

scribed and explained the principal mode of origin whereby the contents of lodes occurred in bunch or pipe-like enrichments connected by a "leader." The varying solutions flowing through the open parts of the fissures acted on the walls and mineralised them, forming "capel," and filled the cavities with ores, so forming the leader-bunches. Some tin-bunches are of such peculiar shape (as, for instance, in some parts of the Great Flat Lode), that unequal impregnation of the country rock is suggested. These bunches are accounted for by Le Neve Foster's hypothesis, but it is probable that the uneven durability of the various parts of the granite have played some part, and that it is to this that the "carbonas," which only occur in granite, may be referred.[1] The conditions described by Foster would make the action complete.

Secondary Concentration.—It is generally admitted that secondary concentration of copper and the chemically allied metals takes place through the agency of ordinary underground waters. The papers of J. F. Kemp[2] and H. F. Bain[3] include masterly contributions to our knowledge of the underground

[1] See "Origin and Development of Ore Deposits in the West of England," J. H. Collins, p. 67. See also "Observations on Balleswidden Mine," p. 5, *Trans. Roy. Geol. Soc. Corn.*, 1879, by Captain T. P. Rowe and C. Le Neve Foster.

[2] J. F. Kemp: "The Igneous Rocks in the Formation of Veins," *Trans. Amer. Inst. Min. Eng.*, vol. xxiv.

[3] H. F. Bain: "Relation of Ore Deposits to the Circulation of Underground Waters," *Twenty-Fifth Ann. Rep. U.S. Geol. Survey*, chap. iv.

circulation of waters, while the paper of Van Hise is full of ideas of much interest.[1] Many parts of the Camborne district, as I am informed by Mr. Joseph Vivian, were marshy, until the extensive development of the mines began some 150 years ago. It is therefore certain that the mines have to pump considerable quantities of purely surface waters. Mr. Kemp has already alluded to the dryness of mines at great depths, and although I have not the precise figures of the amount of water pumped in the past and at present, the evidence in such mines as Dolcoath, Carn Brea, Cook's Kitchen, East Pool, and Wheal Agar show that his observations are correct.[2] The water in the Camborne mines is generally derived from the old workings above, or the cracks in this highly fissured country, which afford easy passage of water, rather than from seepage through solid rocks. In short, the amount which the mine has to pump in depth seems to be mainly dependent on the extent of old workings above.[3] There seems to be much reason for saying that the ground water is confined mainly to fissures, and since this is the case, its lower boundary must be very irregular.[4]

[1] C. R. Van Hise: "Some Principles Controlling the Deposition of Ores," *Trans. Amer. Inst. Min. Eng.*, vol. xxiv.

[2] I am informed by Captain Leonard Thomas that the waters in Levant mine come from above the sixty-fathom level, and the mine is quite dry at the 338-fathom level.

[3] This has no reference to the hot springs occasionally found, as, for instance, in the Clifford mines Gwennap.

[4] J. F. Kemp states that 2,000 feet appear to be the limit of depth of ground water, and in some regions it ceases at 500 feet ("Igneous

The surface waters and rains finding their way below the land surface, do so mainly by fissures, and the subsequent saturation, if any, of the unfissured country rock is a matter of time, and takes place from the fissures. Every miner knows how unexpectedly water is sometimes met with in driving through perfectly dry rocks.[1] Over twenty-three years ago the engine shaft at East Pool mine was being sunk through granite below the 212-fathom level, the nearest lodes, north or south, were many fathoms off; the granite was probably somewhat altered, but was described to me as of the ordinary character; but each successive portion of ground removed from the 212 to the 300 fathom level, by mere contact with air and water from which it had long been protected, became very rotten within a very few weeks of its removal, and resembled ordinary "pot" granite. The weight of the superincumbent mass of rock caused the sides to creep in, so that the shaft had to be timbered from top to bottom. The same phenomenon was observed in other places in both East Pool and Wheal Agar.[2]

Rocks in the Formation of Veins"). I should say tentatively that in the case of the Highburrow and Dolcoath lodes the depth of ground water in them was below the lowest depth occupied by the copper sulphides, *i.e.* varying from about 1,000 feet.

[1] The unsuspected presence of large bodies of water near the working places has sometimes led to disaster. The Wheal Owles accident, some years ago, is a sad instance illustrating the point.

[2] Information from Captain Treloar, underground agent at East Pool and Wheal Agar United.

J. H. Collins has remarked on granite taken from the Beam mine, which decomposed very soon when exposed to atmospheric

In such instances as that at East Pool the decomposition was due to the action of water on either an exceptional kind of granite, or, more probably, on a granite altered, during its consolidation, by vapours not bearing tin ore.

It seems that the denudation that has gone on since the lodes were formed is the process which determined the second concentration of sulphides. "Before the upper portion (of a lode) shares in the disintegration and denudation that are going on at the surface, it has already parted with its metalliferous contents, which have gone to enrich the lode below. Consequently, according to this view, the enrichment of lodes must be descending at a corresponding rate with surface denudation."[1] Professor Emmons has illustrated the processes by which copper ores can decompose into soluble salts, migrate, and, under suitable conditions, regenerate with comparative ease.[2] Tin, on the other hand,

agencies. The granite may have been altered pneumatolytically. See also "The Hensbarrow Granite District," by J. H. Collins, p. 31; also "Fitzmaurice and Stokes on the Nile Reservoir and Sluices, Assuan," pp. 10, 31, 68.

[1] J. B. Hill, R.N. (H.M. Geol. Survey): "The Plutonic and other Intrusive Rocks of West Cornwall in their Relation to the Mineral Ores," *Trans. Royal Geol. Soc. Corn.*, vol. xii. part vii., 1901, p. 586. See also "Secondary Enrichment of Ore Deposits," Professor Emmons, *Trans. Amer. Inst. Min. Eng.*, vols. xxiii. and xxiv., p. 463.

[2] S. F. Emmons: "The Secondary Enrichment of Ore Deposits," *Trans. Amer. Inst. Min. Eng.*, vol. xxiv.

There was an instance of migration of copper in actual process at Great Condurrow mine, where, at the 140-fathom level, a stream of water, with copper sulphate in solution, issued from the lode and precipitated copper on the metal-work in the shaft. Water, at a

and its accompanying vein constituents, are extremely stable, and practically impossible to alter by ordinary weathering processes. The significance of Henwood's statement that hard rocks are more congenial to tin than to copper is, therefore, of great interest. The existence of rich secondary copper ores may imply a fissure once admitting surface waters freely. Immense quantities of black, grey, and yellow copper ores were taken from the Basset lodes, seven or eight in number, to the 110-fathom level, but all of them ceased to be productive after that.[1] Black and yellow copper ores and native copper were also found alongside of tin in the middle lode (which is mainly in granite) at South Condurrow mine, but only to the seventy-fathom level, where the granite is rather rotten. The labours of Mr. Collins have thrown considerable light on the genesis of the deposits in this region.[2] On the whole, from my own observations in the Camborne mines, I am inclined to believe that there is a zone of concentration as regards the copper ores; that is to say, if the surface denudation ceased, the concentration of the copper, by waters percolating through the fissures, would take place at a certain level depending on the nature

temperature of 102° F., was also met with in North Roskear at the 160-fathom level, indicating energetic action.

[1] There was a period of poverty lasting seventeen years at Dolcoath mine before the rich tin was discovered below the rich copper ore which had been worked out.

[2] J. H. Collins: "Cornish Tinstones and Capels," *Journ. Min. Soc.*, vols. iv. and v.

of the fissure, and the ores would not be carried down to a great depth, unless by convection within gaping fissures. The process is one of descent, the ores being within, and contained by the lode itself, and differs from the migration of mineral at great depths due to subterranean circulation connected with eruptive after-actions. I have observed in Cook's Kitchen mine recently incrustations of colloidal silica in the levels about a depth of 150 fathoms, showing how rapidly mineralisation can be carried on by percolation of waters soaking through the gossan and "deads" above. In the case of our copper ores, the lower limit of ore ground seems to have been partly determined by the depth to which the waters could descend in the lode fissures, and the upper limit depends on the amount of water able to penetrate into the lode, and is an uncertain factor.

If these conditions are beyond doubt, there is no reason for assuming that they militate against the profitable exploitation of the valuable ores still remaining in Cornwall. The older generation of miners worked at shallow levels, taking only the richest of the ore, so that with modern engineering methods and dressing plant there is hope of a revival in Cornish mining.

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